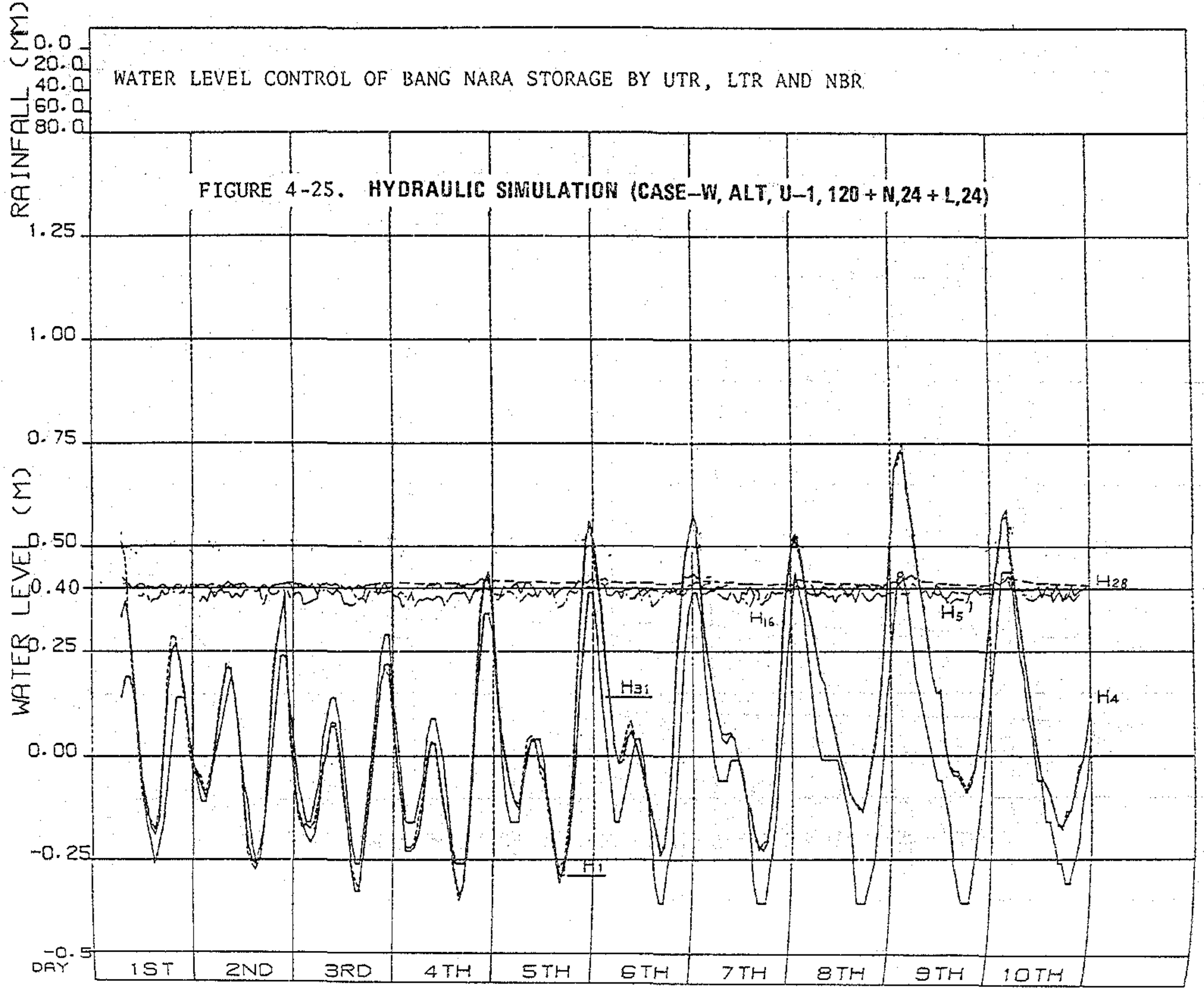


FIGURE 4-25. **HYDRAULIC SIMULATION (CASE-W, ALT, U-1, 120 + N,24 + L,24)**

iii) Consideration

The hydraulic simulations options as described in the previous paragraph have been, in detail, discussed in comparison with the extent of paddy field and rubber area to be inundated. Since it would be considered rather complicated to grasp an entire picture of these hydraulic simulations options, the salient features involved in each option are briefly presented in the following:

MAXIMUM WATER LEVEL AND RELATED INUNDATED AREA

Case	Average Maximum Water Level Within Storage (EL-m)	Maximum Inundated Area (Paddy+Rubber: ha)
1. Case P:	2.20	6,272
	0.06	107
2. Case W/O: No Improvement	2.14	6,165
	0.04, 0.10	71, 177
+ RMI	2.10	6,094
	0.02	35
+ RCI, H28-16	2.08	6,059
	0.04	71
+ RMI+RCI, H28-16	2.04	5,988
	0.13, 0.03	230, 53
3. Case W: ALT U-1, 180+L,24+N,24	2.01	5,935
ALT U-1, 120+L,24+N,24+0.05	2.11	6,112
ALT U-1, 120+L,24+N,24 +RMI+RCI, H28-16	2.09	6,077
	+89	
	0.03, 0.10	53, +178
ALT U-2,60+L,24+N,24 +RCI, H28	2.11	6,122
ALT U-1,120+L,0+N,24	2.24	6,343

Elevation (EL-m)	Paddy Field Area	Paddy Field Cumulated	Rubber Area Area	Rubber Area Cumulated	Total Area	Total Cumulated
	(ha)					
0 - 1	1,940	1,940	37	37	1,977	1,977
1 - 2	3,800	5,740	140	177	3,940	5,917
2 - 3	1,620	7,360	153	330	1,773	7,690

As a matter of fact, each option of the hydraulic simulations indicates that all of the proposed gates to be equipped at the tidal regulators would take a form of full opening during majority of the target flood, specifying that the water level immediately downstream of regulators is quite higher than the ocean water level and also has less response to the tidal oscillations since the tidal regulators are located far upstream of the river mouths taking a large flow resistance along the river channel between the mouth.

Major findings on locating and sizing of the proposed tidal regulators which have been obtained from the hydraulic simulations options for the target flood and other cases are given below:

- An effect of the flood mitigation to a meaningful extent with the provision of tidal regulators could not be identified even when a larger width of the gate opening is installed at each site together with the Narathiwat mouth improvement and the river channel improvement with excavation of the narrow cross-sections along Mae Nam Bang Nara from the Nam Baeng diversion to the Upper Regulator site. (refer to Table 4-4)

- It would be difficult to eliminate a lower tidal Regulator and provide with the river closure only at this site due to a higher water level in its immediate upstream during the flood, since the cross-sections from this site to the Nam Baeng diversion have not a sufficient capacity to convey the flood water to other regulators. Another reason to provide the Lower Tidal Regulator would be to release water which would be accumulated at the dead corner of the Bang Nara water storage in terms of water quality. (Table 4-5)

- Two alternative sites have been proposed for the Upper Tidal Regulator, called "UTR-1" including the Yakang river in the water storage and "UTR-2" in the upstream of the Yakang river connection. (Table 4-2)

- Moreover, additional alternative plans in relation to UTR-1 and LTR were studied on the necessity of the tidal regulators with the fixed weirs on the major bed in addition to the gated weir. (Table 4-3)

  In the case of the UTR-1, the width of the fixed weir is about 600 m at maximum. And also in the case of the LTR, the width of that is about 500 m. The purpose of the alternatives is to decrease the maximum inundation depth and to shorten the duration of inundation by means of construction of the fixed weir in addition to the gated weir.

  As a result of hydraulic simulations which have a part of the fixed weir, the eradicable effect of the mitigation of inundation is not realized as compared with the case of the gated weirs only even though its width is maximum. Particularly, when LTR has the fixed weir on the major bed, it has an adverse effect by the adverse flow from the Kolok river.

° The flood simulation study shows that the most reasonable size of two alternatives with the above-mentioned concept which can be given below;

- ALT U-1, 120 + L,24 + N,24 (Case 1)
- ALT U-2, 60 + L,24 + N,24 + RCI, H28 (Case 2)

One of the distinct features in the water storage to be established by UTR-1 is that while the major storages are located along the course of the Bang Nara river up to LTR and NBR, a greater part of the water supply into the storage for more effective utilization during the non-flood season comes from the Yakang river without any cost.

° Additional flood simulation study for the best case of "ALT U-1, 120 + L, 24 + N, 24" has been made incorporating the side flow of Mae Nam Kolok into the model to identify the effectiveness of the proposed tidal regulators' arrangement. The following cases have been examined:

Case	Average Maximum Water Level Within Storage (EL-m)			Maximum Inundated Area (Paddy+Rubber:ha)		
1. Case P:	2.32			6,486		
2. Case W:		-0.10	-0.21		-220*/	-374
ALT U-1,120+L,24+N,24	2.22			6,266		
ALT U-1,120+L,24+N,46	2.11			6,112		

*/ ..... *This figure would be divided into 160 ha for the paddy field and 60 ha for the rubber planted area.*

Period of Inundation	Land above EL+2.0m		Land above EL+1.5m	
1. Case P:	75hrs.		162hrs.	
2. Case W:				
ALT U-1, 120+L, 24+N, 24	68hrs.	-7hrs.	154hrs.	-8hrs.
ALT U-1, 120+L, 24+N, 46	4hrs.	-71hrs.	82hrs.	-82hrs.

- In case W "ALT U-1, 120 + L, 24 + N, 24" a significant effect has been recognized that the Lower Tidal Regulator would function to eliminate the current flood invasion into Mae Nam Bang Nara due to the flooding of Mae Nam Kolok. This flood invasion amounts to some 10 million cu.m being equivalent to the channel storage volume of Mae Nam Bang Nara.

- In the case W "ALT U-1, 120 + L, 24 + N, 48" which intends to expand the width of existing Nam Baeng Channel to 90 m and the total gate opening width of existing Nam Baeng regulator to 46 m, the inundation period would be greatly reduced. RID has, however, implied that at this stage, there would not be any opportunity to widen existing Nam Baeng system, and this alternative would be left over for future consideration.

° During the rainy season, it is necessary to maintain the flood sluice way with safety. Figures 3-5-1 to 3-6-16 in Appendix III show the flooding stages which are equal to the heavy rainfalls with 3, 50, 100 and 200 yr-return period, around the Bang Nara river basin as compared with the present condition and the with project condition. After construction of the tidal regulators, the flooding stage as a whole would be slightly mitigated with timely gate operation. According to these figures, it is imperative that the gate control of three regulators must be executed fractionally.

° Figures 4-24 and 4-25 show the hydraulic behavior in the Bang Nara storage after construction of the tidal regulators during the non-rainy period. When the gates of UTR are closed for a long time and the gates of LTR and NBR are operated, it is very difficult to keep the normal impounding water level as a whole in the storage. To this end, double leaf gates with over flow type should be installed, so that the normal impounding water level would be kept stably.

4.2.3. Target Dimensions of Tidal Regulators

(1) Location and Gate Opening Width

Two alternative sites have been proposed for the Upper Tidal Regulator, called UTR-1 including Mae Nam Ya Kang in the water storage and UTR-2 in the upstream of Mae Nam Ya Kang connection. The flood simulations study shows that the most likely reasonable size of two alternatives would be given below:

- ALT UTR-1, 120m
- ALT UTR-2, 60m

Construction cost of two alternatives is discussed below:

(a) Approximate construction cost for UTR-1 would be 303 million Baht, while that of UTR-2 would be 224 million Baht, resulting in the cost reduction of UTR-2 by 24 percent (See para. IX.1.2 of Appendix IX).

(b) UTR-2 is not in a position to absorb all of the flow from Mae Nam Ya Kang. This is clearly related with a fact that the irrigation potential at UTR-1 is quite low when compared with that of UTR-1. To cope with the irrigation potential identical with that of UTR-1, a diversion of the Ya Kang water*/ to the Bang Nara water storage via Khlong To Che which would be deemed the most appropriate alternative should be provided with an approximate cost of 125 million Baht. When this cost is added to that of UTR-2, the total initial construction cost for UTR-2 and Ya Kang diversion would be 349 million Baht which exceeds that of UTR-1. Detail of the cost comparison is compiled in para.IX.1.2 of Appendix IX.

*/...Diversion weir : 60m-gated at Ban Cha Nu Rong Bu Ro which is located upstream of X 73 (366 sq. km.)

Diversion canal: (1) Capacity of 5 cu.m per sec.
(2) 300m-culvert + 1,500m -concrete lined canal with one railway crossing.

Furthermore, there are two alternatives, one of which is the case that UTR-1 and LTR are provided with a fixed-type weir equipped with apron and riprap (referred to as "With W") and the other of which is the case that they are not equipped with the weir (referred to as "Without W"). Sequent on the comparative study made on both cases in terms of flood simulation, the effect of the case "With W" on the maximum water level and the inundation duration of the Bang Nara water storage would be ignorantly small even if the weir is designed to the longer in its length (refer to Tables 4-2 and 4-3). Therefore, the case "With W" would be deemed unfavourable.

In accordance with the major findings as introduced above, it has been concluded that "ALT UTR-1, 120m" is the best alternative arrangement of tidal regulators for the proposed Bang Nara water storage.

(2) Gate Crest Elevation

The gate crest elevation is obtained by summing the highest high water level (HHWL) or the mean high water springs (HWL) with the tide level deviation and furthermore a margin of safety, so as to prevent the overflow, overtopping, etc. of external tide.

The external tide level and the inner water level conditions are shown in the followings.

(a) External tide level (observed)

	at Narathiwat	at Taba
HHWL	+1.18 m	+1.51 m
HWL	+0.58 m	+0.81 m
MSL	+0.08 m	0.11 m
LWL	-0.35 m	-0.42 m
LLWL	-0.67 m	-0.77 m

(b) Inner water level

(i) Impounding water level

Normal impounding water level	+0.40 m
Minimum impounding water level	-0.20 m

(ii) In the case of flood

	UTR	LTR
At 5-year return period		
- Upstream level		
(gate opened)	EL+2.23 m	EL+1.47 m
(gate closed)	---------	EL+1.18 m
- Downstream level		
(opened)	EL+1.63 m	EL+1.44 m
(closed)	---------	EL+1.58 m

	UTR	LTR
At 50-year return period		
- Upstream level		
(opened)	EL+3.25 m	EL+1.92 m
(closed)	----------	EL+1.80 m
- Downstream level		
(opened)	EL+2.32 m	EL+1.89 m
(closed)	----------	EL+2.20 m

The maximum tide levels of each year are observed in the rainy season in November/December, and it is presumed that there is influence of the flood. Therefore, the mean high water springs is regarded as the tide level for determining the gate crest elevation.

Gate Crest Elevation of UTR

The gate crest elevation of UTR is determined by adding the tidal range and the runup (shallow water significant wave) at the proposed gate location to the high water level estimated at Narathiwat.

HWL (At Narathiwat)	+0.58 m
Tidal Range	0.05 m
Runup	

$$\frac{gH}{U^2} = 0.283 \tanh\left[0.53\left(\frac{gd}{U^2}\right)^{0.75}\right] \tanh\left\{\frac{0.0125\left(\frac{gF}{U^2}\right)^{0.42}}{\tanh\left[0.53\left(\frac{gd}{U^2}\right)^{0.75}\right]}\right\}$$

where H; Wave Height
F; Fetch 1.5 km
U; Wind Speed 15 m/sec
d; Water Depth 5 m

Find H= 0.44 m

Accordingly, the gate crest elevation of UTR has been calculated as follows:

$$EL+0.58+0.05+0.44 = EL+1.07m \doteqdot EL+1.1m$$

Gate Crest Elevation of LTR

LTR functions to prevent not only the invading tidal water but the back flow of the river at the flood time so that the gate crest elevation has to be determined as to meet the requirements of both functions. Comparing the tidal level with the outside water level at the flood time with a 5-year return period, the latter is as high as 0.8 m than the former. Therefore, the gate crest elevation of LTR has been determined at EL+1.60 m. The gate would be overtopped by assuming the flood level with the probability of exceedance, but the Bang Nara water storage would not be much affected due to non-invasion of sea water and a short overtopping period.

(3) Impounding Water Level and Water Abstraction Management

Taking into account the tidal gate crest level of EL + 2.50 m at existing Nam Baeng regulator, EL + 1.10 m at UTR and EL + 1.60 m at LTR which are given in para. 4.2.3. of this chapter, it would be possible to provide a fresh water storage with a normal impounding water level of EL + 1.10 m. The proposed water storage, however, differs from the usual reservoirs on the hill side in that the environmental, wildlife and river side communities regimes are currently based upon the history of water level along Mae Nam Bang Nara which are tidal.

Development of the non-bounded freshwater storage under the proposed Project which is considered as an initial step along Mae Nam Bang Nara would be conditioned by the limits on upper and lower operating levels which restrict a developable storage volume. If a top water level higher than the present one* is taken, extensive paddy and rubber areas would be submerged and cause the enormous disruption around the storage. The lowest operating water level would be reduced in drier years falling under the influence of evaporation from the storage and swamps with an effect to be increased by irrigation abstraction, and there is a danger that the swamps or the shallowest part of the storage would evaporate to a condition approaching dryness and the sulfate ions from the leachate of actual acid sulfate soils around the storage would increasingly flow into the storage.

*/ ... At the water level of EL + 1.10 m, the paddy field of 2,700 ha and the rubber area of 60 ha would be submerged.

As stated in Figure 3-10, para. 3.3.4. of Chapter 3, the water level information along Mae Nam Bang Nara have been obtained by the three JICA provided automatic water level recorders and indicate the water level fluctuation outside the flood season as summarized below:

(unit: EL-m)

	x160 at UTR-1		x162 at Nam Baeng Bifurcation		x161 at LTR	
	High	Low	High	Low	High	Low
Spring Tide	0.74	-0.40	0.70	-0.26	1.05	-0.57
Average	0.53	-0.02	0.58	+0.12	0.66	-0.20
	Ave. 0.26 m		Ave. 0.35 m		Ave. 0.23 m	

When the above mentioned information are compared to the contour lines in the 1:10,000 topographic maps, major part of the Laem Bang Nara II Forest Reserve which is the swamp forest near the water level recorder atX162 would need a careful attention in terms of environmental constraints.

Although the relationships between the swamp water level and maintenance of existing plant communities in the Laem Bang Nara II Forest Reserve have not been made clear, the increased duration of higher impounding water level and also the increased magnitude of seasonal fluctuations in surface and groundwater level in such swamp would result in substantial damages in species composition and most probably dieback in the low-lying zones of the proposed water storage, thus inviting the serious consequences on the long-term viability of its swamp ecosystem inclusive of both plant and wildlife populations.

Keeping the above factors in mind, the normal impounding water level of the Bang Nara water storage under the proposed Project has been taken at EL +0.40 m which is slightly higher than the present average one of EL + 0.35 m at Nam Baeng bifurcation recorder while it is greatly lower than the high water levels by tidal motions. The latter consideration would eliminate the present inconvenience from temporarily extended shallow flooding over the low-lying paddy and other land along Mae Nam Bang Nara during high tides. With the normal impounding water level of EL + 0.40 m, existing river channel of 5.1 sq.km and major part of the Laem Bang Nara II Forest Reserve of 8.8 sq.km with a total of 13.9 sq.km or 1,390 ha would be the water surface area of the proposed Bang Nara storage, although the storage edge within the swamp forests is not clearly defined around much of the perimeter. It is noted that under this condition, there is no cultivated land to be submerged or no land to be compensated with the Government fund.

While the impounding water level behind three tidal regulators would remain close to top water level of EL + 0.40 m throughout the off-flood season taking into consideration the higher lowflow availability of many tributaries, the impounding water level would drop in drier years with the water extraction by pumping irrigation. The water level drawdown should be confined to a limited extent by the water needs of existing swamp forests, the level of which follows the current water level. With respect to this environment constraint, attention has been paid to the present average low water level during the spring tides of EL -0.26 m near the Laem Bang Nara II Forest Reserve, and the lower limit of impounding water level has been taken at EL -0.20 m. In addition, this water level would not be criticized by the problems for storage side dwellers and would contribute to avoid the generation of acidic water from some of the tributary basins.

In a dry year, it is probable that the pump operators would be more responsive to the needs of farmers to avoid crop loss than to the environmental and social needs of other communities to keep away from excessive water level drawdown. There appears to be every possibility of the abstraction rules being "bent" in favour of the farmers in such case. Excessive drawdown for long period could cause irreversible environmental damage to the ecology of swamp forests as well as the status of potential acid sulfate soils, and would temporarily make a series of separated shallow ponds causing a fish kill and other losses. It is, therefore, essential to be satisfied that the abstraction rule to cease when the storage water level fell to EL -0.20 m is sacrosanct, and the system operators and their RID superiors accept the discipline that this entails. In conclusion, it can be mentioned that yield of the Bang Nara fresh water storage with an effective capacity of about 4.5 million cu.m is severely limited by the need to limit the drawdown for environmental reasons, and the water balance computations which are discussed in next paragraph have been based upon this water abstraction management.

(4) Salt Water Freshing Process

The Bang Nara water storage is provided by replacing the saline water with the freshwater inflow. The saline water replacement in this case is referred to as salt water freshing process. Such process can be classified methodologically as follows:

- Freshing by the Tidal gate operation only. (Type i)
- Freshing by the Tidal gate and desalinization conduit. (Type ii)
- Freshing by the Tidal gate, desalinization conduit and desalinization pump. (Type iii)

On the other hand, the freshwater storage is generally classified from the viewpoint of density current into (1) the two-layer type and (2) the mixing type. This classification is roughly explained by the following parameter:

$$a = \frac{\text{Annual inflow into the reservoir}}{\text{Total volume of reservoir}}$$

$$b = \frac{\text{Total inflow of each flood}}{\text{Total volume of reservoir}}$$

$a < 10$	two-layer type
$a > 20$	mixing type
$0.5 < b < 1$	two-layer type
$b > 1$	mixing type, disappearing the internal boundary layer

The two-layer type of density current is clearly divided into the fresh water layer and the saline water layer, and the salinocline is formed at the boundary layer. On the other hand, the mixing type of density current is not divided into any layer and its vertical distribution of salinity is approximately uniform. The salt water freshing process is closely related with the above mentioned types of density current in the subject reservoir. Because the two-layer type has high density of salinity in the lower layer, the desalinization conduit or the desalinization pump is employed for the desalinization from lower layer so that the upper layer can be kept fresh. Since the salinity of the mixing type is almost uniform vertically, the desalinization can be processed effectively by drainage sluice operation only.

In selecting the parameter of the type of density current, the Bang Nara water storage has its own values as follows:

$$a = \frac{\text{Average annual inflow}}{\text{Total volume of reservoir}} = \frac{1,713.1 \times 10^6}{17 \times 10^6} = 100.8 \gg 20$$

$$b = \frac{\text{One year return period flood inflow}}{\text{Total volume of reservoir}} = \frac{196.8 \times 10^6}{17 \times 10^6} = 11.6 \gg 1$$

As a result of the above estimation, the Bang Nara water storage would be classified to be a strong mixing type. Therefore, the desalinization process by the drainage sluice only (Type i) is suitable for the Bang Nara water storage.

The Jansen's formula which is one of the desalinization process equation would be applicable to estimate the mixing type storage:

$$C = C_2 e^{-\frac{Q}{V} t} \quad (ton/m^3) \quad \ldots\ldots\ldots (1)$$

Where C = mean salinity at any time in the reservoir (ton/m^3),

C_2 = initial salinity in the reservoir (ton/m^3)

Q = inflow to the reservoir (m^3/s)

V = total volume of the reservoir (m^3)

t = duration time from final closing (sec).

The desalinization process analysis should be dealt with as time series. On the other hand, the most dominant factor to the desalinization process is the freshwater flow amount into the storage. Even if a final closing of the Bang Nara water storage is made during the beginning of the dry season, the initial desalinization process can be finished within 40 days:

$$C = 0.002 \times e^{-\left(\frac{16.0}{17\times10^6} \times 86,400\times40\right)} = 0.000773\ (ton/m^3)$$
$$= 773\ ppm < 1,000\ ppm$$

Where $C_2 = 0.02\ ton/m^3$

$Q = 16.0\ m^3/s$

$V = 17 \times 10^6\ m^3$

Therefore, it appears that the initial desalinization process would proceed within the short duration without any difficulty.

After completion of the initial desalinization process, the Bang Nara water storage should be maintained with the low saline water. In the case of the Bang Nara river basin, there is monthly rainfall more than 50 mm even in the dry season so that the river inflow into storage is abundant.

As a whole, there is the strong mixing type of density current which has approximately uniform distribution for the vertical salinity in the tidal Bang Nara river. Because the two-layer type of density current appears between the river mouth and the tidal regulator, it is forecasted that the salt intrusion through the tidal gate operation which is caused by the saline wedge will occur after construction of the Bang Nara water storage.

Then, non-uniform flow analysis on the two-layer type of density current has been executed for the purpose of estimating the saline wedge as shown in the Figure 4-26 where the subscripts 1 and 2 refer to the upper layer and the lower layer, respectively. When the density current is in a form of steady flow and i_f is taken of friction slope, the equation of motion may be written as follows:

$$\frac{\partial}{\partial x}\left(\frac{\alpha v^2}{2g}\right) = -\frac{\partial}{\partial x}\left(\frac{p}{\rho g} + z\right) - i_f$$

$(p/\rho g + z)$ may be written by using the symbols in Figure 4-26 as

Upper layer: $\frac{p_1}{\rho_1 g} + z = h_1 + h_2 + z_o$

Lower layer: $\frac{p}{\rho_2 g} + z = (1 - \varepsilon)\, h_1 + h_2 + z_o$

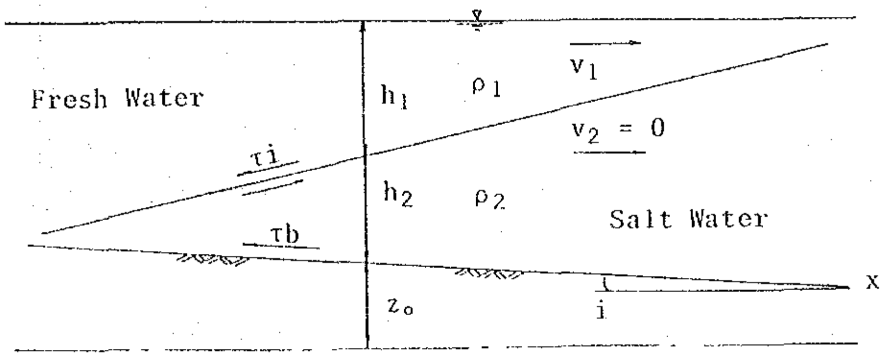


FIGURE 4-26. PROFILE OF TWO LAYERS DENSITY CURRENT

Where $\varepsilon = (\rho_2 - \rho_1) / \rho_2$

z_o = elevation of river bed and i_f = friction slope (τi and τb correspond to shearing stress because of internal boundary friction and friction of river bottom, respectively). Friction slope(i_f) varies with the coefficient of friction loss by fi of boundary layer between the fresh water layer and the saline water layer. fi is the function of Reynolds number (Re) and Froude number (Fr) and is written as:

$$fi = C \cdot [Re \cdot Fr]^{-n}$$

In the case of Mae Nam Bang Nara, there are not enough observation data available to estimate C and n, so that it is assumed that fi is 0.01 with reference to Figure 4-27 and the saline wedge analysis to be executed.

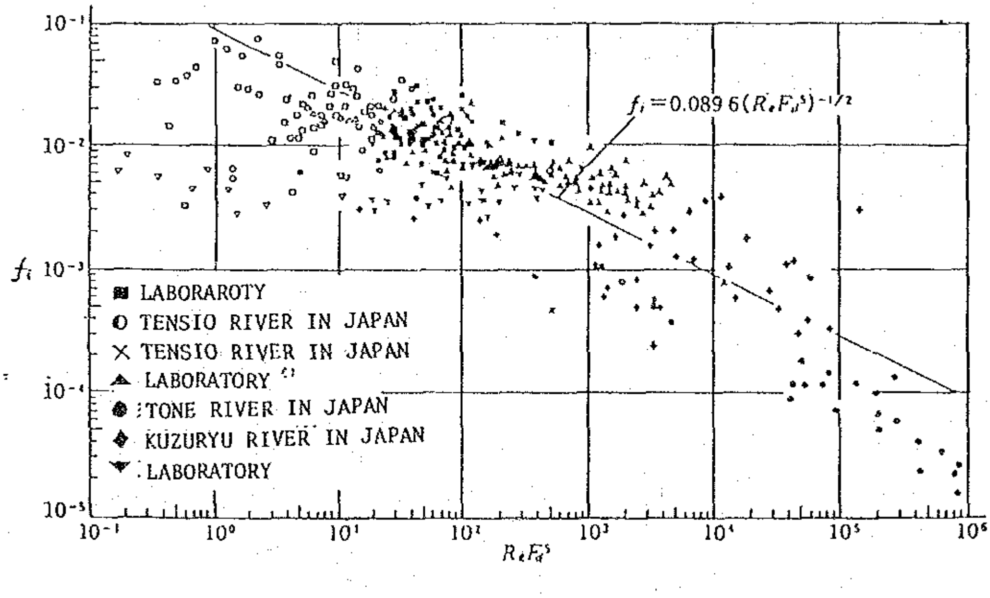


FIGURE 4-27. RELATIONSHIP BETWEEN COEFFICIENT OF INTERNAL RESISTANCE AND ReFd5

The condition of the saline wedge in the Bang Nara river has been examined at the various tide levels and river discharges for the river cross-sections from the river-mouth of Narathiwat to upstream. The results as shown in Figure 4-28 and Figure 4-29 indicate that when the tide level is low,the saline wedge would not intrude into the Bang Nara water storage even though the river discharge is small (13 m^3/s), but when the tide level is high, the saline wedge would intrude into the storage even though the river discharge is large (20 m^3/s). This consideration has been incorporated in Figure 5-2, para. 5.1.4. "Mode of Operation".

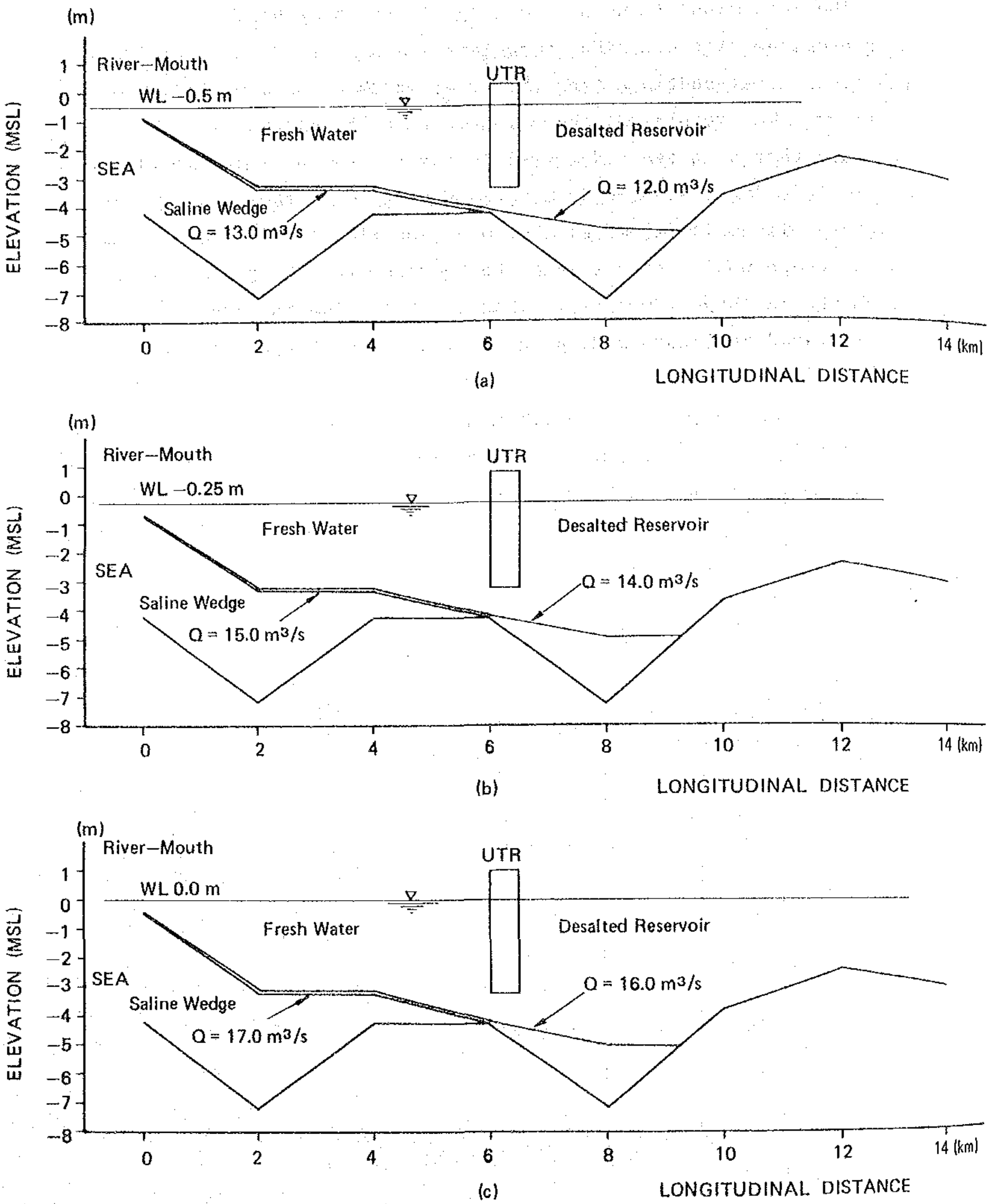
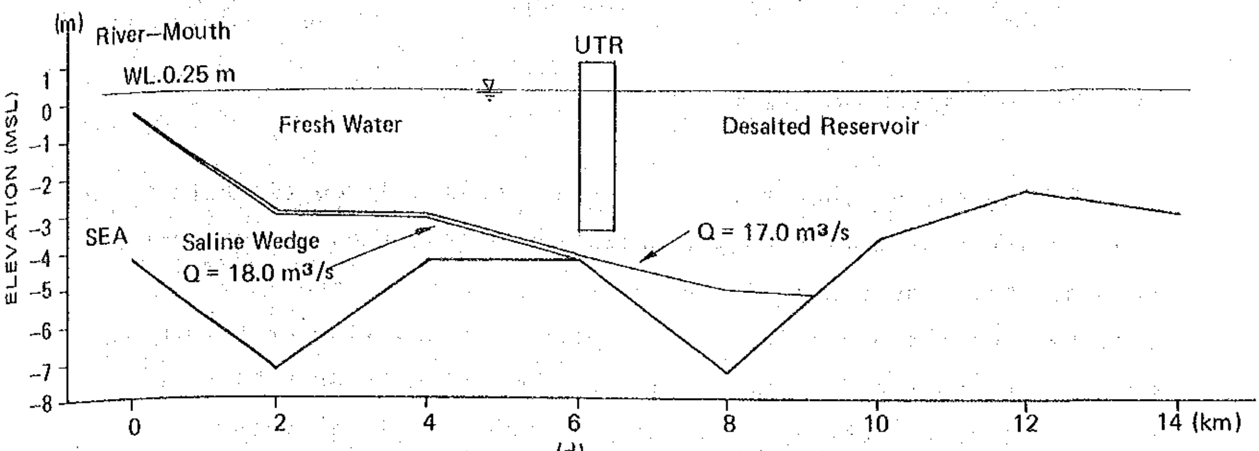
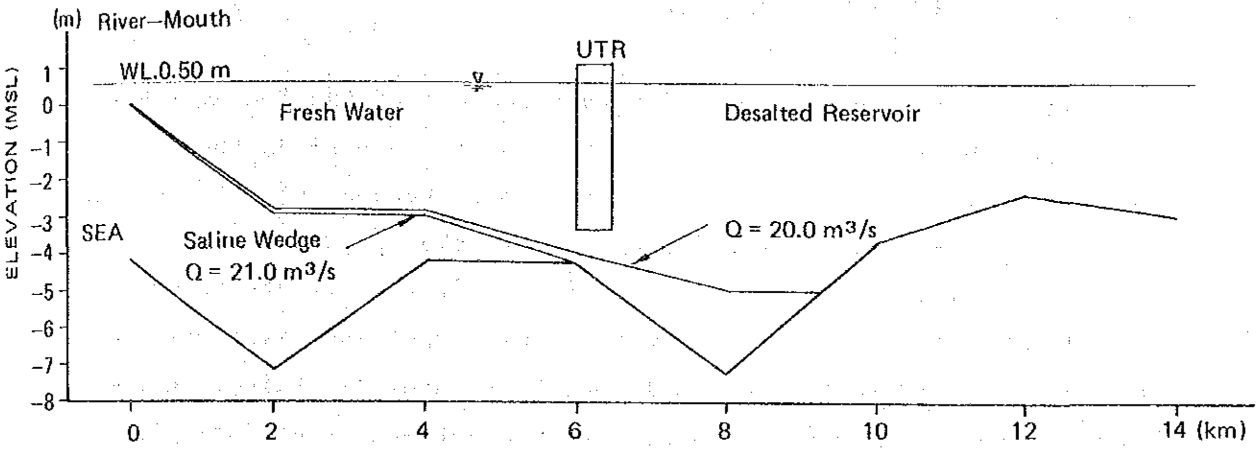


FIGURE 4-28. **PROFILE OF SALINE WEDGE FOR EACH TIDE LEVEL AND DISCHARGE**



(d)



(e)

FIGURE 4-29. **PROFILE OF SALINE WEDGE FOR EACH TIDE LEVEL AND DISCHARGE**

4.2.4. Storage Water Balance Simulations

(1) River Maintenance Flow

During the northeast monsoon, the floods will continue to flush the estuary system with proper operation of the tidal gates taking into account less regulating capacity in the Bang Nara water storage. On the other hand, the present estuary flow at Narathiwat during the non-flood period is mainly dominated by such tidal flow as flood tide and ebb tide discharges with some fresh water contribution to the ebb discharge from the upstream basins of Mae Nam Yakang and Mae Nam Bang Nara.

In the case "UTR-1" that incorporates all of the Yakang river flow into the water storage during the non-flood period, there would be only the tidal flow along the lower reaches of Mae Nam Bang Nara when no release of the storage water takes place from the regulator. This would invite some of the adverse effects to the Narathiwat estuary in terms of water environment and river entrance sand bar. Some fresh flow should be, therefore, maintained in the lower reaches of Mae Nam Bang Nara to prevent sea water intrusion and carry away waste after construction of the tidal regulator in order to conserve the water-related environmental conditions as are currently seen in the case without the tidal regulator.

It is, therefore, considered that 5 cu.m per sec of the minimum river maintenance flow for the Narathiwat estuary during the non-flood period which is equivalent to that equal to the 30 day, one in 5 yr-low or one in 10 yr-low flow (5.3 cu.m/sec or 4.8 cu.m/sec, respectively) duing that time would be at all times released from the UTR. It is also expected that such river maintenance flow could eliminate any particular effect on the regular maintenance dredging along the Narathiwat estuary annually being carried out by HD. This condition has been employed to determine the water available for irrigation in the water balance simulation study by using the Bang Nara storage.

Since a present portion of the Bang Nara runoff in Mae Nam Kolok during the non-flood period is negligibly small as compared with a total flow at Kolok river mouth, any consideration to release the maintenance flow from LTR is not given, while it would be required to discharge some of the stagnant water in the Bang Nara water storage from LTR as occasion needs to mitigate the storage's water quality deterioration.

(2) Sediment Transport and Deposit

(i) Suspended Sediment

Since no observed sediment data are available in the Study area, the data actually measured at Mae Nam Kolok in 1981 and 1982 have been applied to estimate the volume of sediment of Mae Nam Yakang, because Mae Nam Kolok is adjacently located at the objective basin and the vegetation and topographic conditions of the Mae Nam Kolok basin are similar to those of the Mae Nam Yakang basin.

The suspended sediment curve of Mae Nam Kolok is shown with the following equation:

$$Qs = 0.459 \times Qw^{1.694}$$

where Qs : Suspended sediment load (ton/day)
Qw : Discharge (cu.m/sec)
(Refer to Figure II-2-21 of Appendix II)

The discharge data as presented in para.3.3.4 of Chapter 3 are employed to calculate the sediment volume of the Mae Nam Yakang basin. The monthly mean suspended sediment loads for 31 years are explained in Table 4-7. The total amount of the sediment load during 9 months from February to October is calculated at 29,800 tons, and the largest volume of 110,800 tons during the said period appears in 1984. (Refer to Figure II-2-22 of Appendix II)

TABLE 4-7 MONTHLY MEAN SUSPENDED SEDIMENT

(unit: 1,000 ton)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
22.4	4.0	2.5	1.1	2.8	2.6	2.5	3.5	4.6	6.2	27.5	46.0	125.7

In comparing the said specific value with those of the neighboring basins, the difference is not large as shown in Table 4-8. In general, the soil in those basins changes from grey to red-yellow pozolic type in the upstream and the alluvial soil in the downstream.

(ii) Bed Load

Judging from the grain size accumulation curve of Mae Nam Kolok which is developed based on the materials collected in the GRBDS, the river bed of Mae Nam Yakang seems to consist of fine sand ranging from 0.5 to 2.0 mm. The discharge is little in the off-season and the river slope is gentle. Consequently, it can be assumed that the amount of bed load would be negligibly small in comparison with the amount of the suspended load. (Refer to Figure II-2-23 of Appendix II)

TABLE 4-8 ANNUAL SUSPENDED SEDIMENT

River	Sediment Load (t/year)	C.A (sq.km) & Annual Rainfall	River Length	Slope of River Bed	Rate of Sediment Load (t/year/sq.km)
Mae Nam Yakang (Narathiwat)	125,728	724 (2,499 mm)	75.5	0.0003 (32 km)	173.7
Mae Nam pattani* (Pattani)	353,220	3,295 (1,816)	-	-	107.2
Pak Panang River** (Pak Panag)	234,000	- (2,614)	110	0.00002 (50)	-
Khlong Yai** (Chumporn)	536,000	1,916 (2,097)	120	0.0004 (50)	279.7
Tapi River** (Bandon)	1,311,000	12,631	250	0.00005	103.8

Note: The figures in parentheses mean annual rainfall in mm and the length from the river mouth in km. The location of those observation points are shown in Figure II-1-1 of Appendix II.

Source : * - Hydrology Division, RID
** - The report titled as "Dynamic Characteristics of Nine Southern Rivers of Thailand" by Mr. Hussain Sadrul, AIT

(iii) Deposit

The proposed tidal gates are to be closed to store water and to eliminate the intrusion of saline water into the Bang Nara water storage during the non-flood season and is to be opened to release the flood discharge and to flush out the sediment deposits during the flood period because the amount of the flood discharge is too large. When the bulk density of sand is taken at 1.7 ton per cu.m, the total amount of the sediment load during the non-flood period would be as follows:

	Weight (ton)	Volume (cu.m)
Mean total load	29,800	17,500
Max. total load	110,800	65,200

When the mean and maximum sediment discharges are deposited on the storage bottom in the immediate upstream of the UTR, the top elevation of such sediment deposit would be at EL -6.32m and -5.48m, respectively. While these deposits are constantly accumulated in such storage bed for the long period without any flush-out, the elevation of the river bed which fills up with the deposits would go up to the elevation of EL -4.0m which is equal to the elevation of the UTR's sill. The required time is estimated as follows:

Storage capacity at elevation of EL - 4.0 m	:	262,200 cu.m
Mean sediment load during the non-flood season	:	17,500 cu.m
Time for filling deposit: 262,200/17,500	:	15 years

The top elevation of sediment deposit would, therefore, reach to EL -4.0m for 15 years. There would be no problem that the deposits are over the elevation of the UTR's sill, because grain size of the deposit from Mae Nam Yakang is small and the flood discharge could steadily flush-out such sediment to the downstream of the UTR. (Refer to Figure II-2-24 of Appendix II.)

(3) Basic Condition of Water Balance Simulation

(i) Effective Rainfall

In general, it is important to estimate an amount of effective rainfall for irrigation, because the amount of effective rainfall usually affects not only a scale of the storage but also its investment cost. The Study area seems to enjoy rainfall throughout a year. About 60 percent of the annual rainfall is mainly observed during three months from October to December. In other months, monthly rainfall of less than 200 mm is recorded. Especially, during the months of February to April, the amount of monthly rainfall would reach less than 80 mm, and the number of rainfall days would be a few, that is, the high intensity of daily rainfall occurs.

In this Study, the following equation on the daily basis would be used in order to prevent over-estimate or less-estimate of effective rainfall for the paddy irrigation:

$$ERi = SW_{i-1} + Ri - WRi$$

Where

- ERi : Effective rainfall of i(th) day in mm
- SW_{i-1}: Stored water depth of i-1(th) day on a field in mm

Ri : Daily rainfall in mm

WRi : Water requirement in mm
(Evapotranspiration + percolation)

When a water depth of i(th) day on a field overtops the maximum height of a paddy dike or a notch, the amount of effective rainfall of i(th) day is limited up to the height of the dike or the notch of 250 mm which is seen in the Study area. (Refer to Figure VIII-2-1 in Appendix VIII)

For the upland crops, the U.S. Department of Agriculture's Soil Conservation Service has developed a procedure for estimating effective rainfall by processing long term climatic and soil moisture data. A comprehensive analysis was made by perusing 50 years of precipitation records at 22 experimental stations representing different climatic and soil conditions. The soil moisture balance was worked out for each day by adding effective rainfall or irrigation to the previous day's balance and subtracting consumptive use. To avoid a high degree of complexity, neither the soil intake rate nor rainfall intensities are considered in this method.

From total rainfall and monthly consumptive use, effective rainfall values are computed in Tables VIII-2-1 and -2 in Appendix VIII). The monthly effective rainfall cannot exceed the rate of consumptive use. If it does, the lower value of the two is taken.

(ii) Cropping Calendar

In order to effectively utilize water in the Bang Nara storage, a double cropping system would be recommended to boost and to stabilize a farm income of inhabitants in the Area. According to the explanation in para. 4.4.1 of this Chapter, two crops such as paddy in the main-season and other upland crops in the off-season are incorporated into the Project plan.

The recommended varieties of paddy such as the improved local variety (ILV) and the high yielding varieties (HYV-RD13 and HYV-RD7) would have the growing period of 150 days, 140 days and 120 days from transplanting to harvesting, respectively. The former two varieties are categorized in photosensitive varieties and the remaining one in a non-photosensitive variety.

The cropping period of the ILV is determined by the inundation conditions, with the target heavy rainfall in 5-yr return period after construction of two tidal regulators, which is transplanted at the first decade of September with a 45-day time lag and the ending period of irrigation is at the first decade of January with a 45-day time lag. This variety is planted at the paddy field below EL+1.8 m considering the allowable depth of standing water. The estimated acreage for this ILV is 3,370 ha. (refer to Figure VIII-2-2 in Appendix VIII)

The second variety of RD-13 is planted at any paddy field higher than EL+1.8m in the Project area which is not inundated during the cropping period. The cropped acreage is given at 4,810 ha.

The last variety of RD-7 with an acreage of 1,600 ha is also selected for gaining more production. However, this variety is classified at non-photosensitive which would plant at any time throughout a year. The computations on irrigation water requirement with relation to effective rainfall, therefore, have been carried out for 30 years except 1965 in order to fix the growing period of the RD-7 variety. The analysis of 26 cases that the preparatory work of the first case is starting on the 1st day of June and such works of the following cases are delayed by every 5 days, has been done. When the preparatory work for the HYV RD-7 starts on the 1st day to the 16th day of September, irrigation requirement could be minimized. Table 4-9 is presented for more detail. Because before 1st of September, the paddy cultivation can not effectively use rainfall during the main-season and after 21st of September, the later stages of the paddy growing season meet the less rainfall.

Table 4-9 OCCURRENCE OF MINIMUM IRRIGATION WATER REQUIREMENT

Jul.						Aug.					
1st*	6th	11th	16th	21st	26th	1st	6th	11th	16th	21st	26th
1	1	1	2	2	3	2	3	3	4	5	4

Sep.						Oct.					
1st	6th	11th	16th	21st	26th	1st	6th	11th	16th	21st	26th
9	12	13	10	3	5	4	3	n.a	n.a	n.a	n.a

Note: (1) 1st means that the irrigation starts at the 1st day of July.
(2) "n.a" is an unanalysis case.
(3) The above occurrence numbers are counted by the data which are the three numbers from the lowest one in every year.

As second crops, upland crops can be introduced in the Area because of no limitation of climatological conditions on farming. The most suitable cropping period of the crops is also analyzed by the amount of irrigation water requirement with using same procedure for paddy (HYV RD-7) discussed above. The analysis has indicated that the cropping calendar on the later starting time of the growing period shows the smaller amount of irrigation water requirement than that of the early one, because upland crops on the later one can meet much rainfall. However, the growing period of the upland crops can not move too later or can not overlap with the paddy growing. From the viewpoint of labor distribution, maintenance and rehabilitation of irrigation and drainage canals and other farming works, no farming period of at least one month between the harvesting of upland crops and the cultivation of paddy, would be necessary. This is a limitation to determine the suitable growing period of upland crops. Consequently, the growing periods of paddy would mainly start in September and that of upland crops in April. (refer to Figure VIII-2-3 in Appendix VIII)

(iii) Irrigation Efficiency

Irrigation efficiency, generally, consists of conveyance efficiency, field canal efficiency and field application efficiency.

In the Bang Nara irrigation program, irrigation water is conveyed up to the certain point near the command area through natural canals or proposed farm drains. In the case of portable pumping system in the Project, Stage I, lifted water would directly serve a farm land through a farm ditch as an on-farm facility. In the case of the fixed pump irrigation system in the Project, Stage II, main and lateral irrigation canals would be provided to deliver irrigation water through a farm ditch to a farm land. Considering these conditions, the following irrigation efficiency would be applied for irrigation planning:

For Paddy Cultivation

Efficiency	Pumping System: RID Pump	Pumping System: WUG's Pump
Conveyance	0.9	-
Field canal	0.8	0.8
Application	0.75	0.75
Total	0.54	0.60
Rate of Commanded Area	50%	50%
Weighted Average	:...... 0.57 ....:	

For Upland Crop Cultivation

Efficiency	Pumping System: RID Pump	Pumping System: WUG's Pump
Conveyance	0.9	-
Field canal	0.8	0.8
Application	0.6	0.6
Total	0.43	0.48
Rate of Commanded Area	50%	50%
Weighted Average	:...... 0.46 ....:	

(iv) Water Requirement on Preparatory Work

a) Paddy

Irrigation water would be provided for the preparatory works such as ploughing, harrowing and land leveling before transplanting of paddy when the farmers meet no adequate amount of rainfall. The amount of water requirement on the preparatory work (WR) would be calculated by the following equation:

$$WR = SW + S1 + S2 + EV + P + SL$$

Where

WR: Water requirement on preparatory work in mm
SW: Standing water depth in mm
S1: Saturation water of surface soil in mm
S2: Saturation water of sub-surface soil in mm

EV: Evaporation from water surface in mm

P : Percolation in mm

SL: Seepage loss from a paddy dike in mm

- Standing Water Depth

  A standing water depth of 50 mm is assumed for transplanting of paddy.

- Saturation Water of Surface Soil

  The thickness of surface soil is an assumed value of 150 mm and a porous content of 20 percent. Therefore, the amount of water to saturate the top-soil is 30 mm (= 150 x 0.2).

- Saturation Water of Sub-surface Soil

  The thickness of sub-surface layer is assumed 200 mm and a porous content of 15 percent, therefore, the water to be required for saturation of the sub-surface soil is 30 mm (= 200 x 0.15).

- Water Requirement

  The preparatory works would be done in September and October. During this period, the evapotranspiration rate is 4.1 mm/day ((4.2 + 3.9)/2). A duration of the preparatory works is fixed at 20 days before transplanting. During the period, a supplemental water would be given to the field to protect drying-up of soil. The percolation and seepage losses of one millimeter per day should be considered. So, the total amount of water of this item is estimated at 110 mm ((4.1 + 1.0) x 20 = 102 mm, say 110 mm).

- Water Requirement of Preparatory Works

  The amount of water depth of 220 mm (50 + 30 + 30 + 110 = 220 mm) would be necessary for the preparatory works.

- Application of Water

  Water for the preparatory works would be given on a field at three times. The first application of water of 85 mm would be done at 20 days before transplanting, the second application of 85 mm at 10 days before transplanting and third one of 50 mm at one day before.

b) Upland Crops

For cultivation of upland crops, an amount of pre-irrigation would soften the surface soil. The amount of water to wet the surface soil would be calculated at 15 mm (the thickness of the surface soil (150 mm) x 20% (porous content) x 50% (50% of the amount of water to be saturated the surface soil). The evapotranspiration rate during the period from February to April is 6.3 mm/day in average including one mm/day of seepage loss. The period of preparatory works is determined at five days. (refer to para. 4.4 in this chapter) Therefore, the total amount of pre-irrigation water for upland crops is computed at 50 mm (15 + 6.3 x 5 = 46.5 say 50 mm).

(v) Inflow Discharge into the Bang Nara Water Storage

As the inflow discharge data, the results of the low flow analysis described in para. 3.3.4. (2) of Chapter 3 have been employed for the water balance simulation study.

(4) Water Level Drawdown

(i) Study Period for Water Balance Simulation

According to the results of the low discharge analysis in Mae Nam Yakang and other tributaries of the Mae Nam Bang Nara basin, the 30 years from 1955 to 1985 except 1966 because of lacking data, have been taken.

(ii) Limitation

The amount of 1 cu.m per sec would be assumed for the domestic water supply. PWWA explains that the amount of future water demand for domestic use of the Narathiwat residential area would reach 1.55 MCM per annum. The peak water volume, therefore, would be estimated at 0.1 cu.m per sec taking into account the peak rate and distribution losses in 1992. The existing pump station has, however, no intake facility such as a weir across Mae Nam Yakang. Many losses would be needed to take a proposed amount of water for water supply. Therefore, at least 1 cu.m per sec of discharge in Mae Nam Yakang would be secured for the domestic water supply.

For the amount of river mouth maintenance flow, further detailed information are presented in para. 4.2.4.(2) of this Chapter. Consequently, 5 cu.m per sec in total would be released for maintaining the existing downstream river conditions. This amount is secured before using for irrigation purpose. If the inflow into storage is not reached at the above discharge, all of the inflow from the Mae Nam Yakang basin should be used for this purpose, and this means that, in this case, no amount of discharge is for irrigation.

(iii) Irrigation Return Flow

Considering the location of the Bang Nara water storage and irrigation method of paddy cultivation, some amount of return irrigation water would be expected in the area. There is no observation data to estimate an amount of return flow. From the viewpoint of irrigation efficiency of 57 percent for paddy irrigation, the rate of more than 30 percent of the amount of irrigation water for paddy cultivation would be expected to re-use water for irrigation. For the water balance study, the rate of 30 percent of the amount of the paddy irrigation would be assumed to be applied for one of the inflow discharge.

(iv) Basic Equation of Water Balance Analysis

The following equation is applied for the water balance simulation on the Bang Nara water storage. The calculation interval of 10 days is used for the analysis.

$$Q_i = Q_{i-1} + INF_i - ((WR_i - R_i) \times A)/ EFF + RTN_i - EV_i$$

Where

- Q_i : Stored water volume on the i th day
- Q_{i-1}: Stored water volume on the i-1 th day
- INF_i: Inflow from Mae Nam Yakang and other tributaries of Mae Nam Bang Nara on the i th day
- WR_i : Water requirement by crop on the i th day
  $WR_i = ET_0 \times kc$
  ET_0 ; Evapotranspiration by crop
  kc ; Crop coefficient by crop and by growing stage
- R_i : Effective rainfall on i th day
- A : Acreage to be irrigated
- EFF : Irrigation efficiency
- RTN : Irrigation return flow from paddy field on i th day
- EV_i : Evaporation from Mae Nam Bang Nara water storage

(v) Irrigation Method

In order to give easy operation of irrigation system to farmers in the irrigable area, the rotational irrigation system would be advised. (refer to Figure VIII-2-4 in Appendix VIII)

(vi) Basic Concept of Analysis

In consideration of making the large number of beneficiaries under the proposed irrigation programs and keeping higher water level in the Bang Nara water storage during the off-season in order to prevent acid water generation, many alternative cases have been analyzed.

(vii) Water Level Drawdown

With the 30 year-analysis, water level of the Bang Nara water storage seasonally fluctuates. Since the small amount of river flow and the large amount of irrigation water requirement for upland crops are expected during two months of April and May comparing with those of the other months, the most remarkable occurrence of water level drawdown appears during this period, however, it is not so much drawdown excepting three years of 1958, 1959 and 1964. On the other hand, another drawdown would occur in September to the beginning of October. The reasons are that the paddy cultivation already begins and the rainy season does not yet start. Water level in the Bang Nara storage is normally ranging from WL+0.40 to -0.20 m on April, May and September, and a duration of water level drawdown is short. Therefore, it would be no problem to use water for irrigation purpose from the storage.

In other months from October to March and from June to August, the water level would be kept at the normal impounding water level of WL+0.4m. In order to avoid the water level drawdown in the Bang Nara water storage during only foresaid three years, the shortage of irrigation water would occur.

Consequently, the acreage of 9,980 ha which consists of a pumping irrigation area of 9,800 ha and a gravity irrigation area of 180 ha would be irrigated without remarkable water level drawdown on the Bang Nara water storage. (refer to Figures VIII-2-5 to -7 and Tables VIII-2-3 to -9 in Appendix VIII)

4.2.5. Storage Water Quality

(1) Control of Acidic Water Inflow

The major contributors of acidic water flowing into the Bang Nara water storage have been detected as follows:

Khlong Yabi(Kh. Sa Pi Yo); Khlong Ku Bae Ya Hae; Khlong Pileng(Kh. Ai Long); Khlong Sg. Padi(Khlong Nam baeng); Khlong Ban Toei; Khlong To Lang; Khlong Pru Kab Daeng; Khlong Pu Cho Yo Mu and Kh. Bang Son.

Check gates at Kh. Yabi, Kh. Sa Pi Yo, Kh. Pru Kab Daeng, Kh. Ban Toei and Kh. To Lang were already constructed by RID. At Kh. Pileng (Kh. Ai Long), check gates have been already constructed under the Pileng project by RID. However, the existing gates do not always control water level of the rivers in the problem soil areas because of poor operation. Well-managed operation of these gates should be, especially, carried out to control the upstream water level during the dry season.

New check gates proposed at such rivers as Kh. Ku Bae Ya hae and Kh. Sg. Padi would be necessary to control the upstream water level. And, additional check gates would be required at Kh. Bang Toei and Kh. Ban To Lang, because due to higher elevation of a part of the problem soil areas, exisiting gates could not properly control the upstream water level throughout the river course. On the other hand, water level of Kh. Pu Cho Yo Mu and Kh. Bang Son would be controlled by the impounding water level in the Bang Nara water storage because of low elevation less than +1m in the drainage area.

To prevent the potential acid sulfate soil from acidification, the groundwater level should be controlled by proper operation of the check gate facilities in order to keep around 40 cm below from the ground surface. In the area of actual acid sulfate soils, sulfates accumulated in the soil are dissolved by heavy rain at the beginning of rainy season and flushed away in a form of flood to the Gulf of Thailand.

(2) Control of Persistent Chemicals

Presently a number of agro-chemicals are in use. The principal insecticides are made of organic phosphorus and carbonate and organo-chlorine compounds, and the principal fungicides are based on organic sulphur. Other herbicides, rodenticides, and plant hormones are also in use

Among these agro-chemicals, the organo-chlorine insecticides in particular have been suspected of harmful effects on human health. Even now BHC (benzene hexachlorides) is utilized in some quantities than other organo-chlorine insecticides. The use of these insecticides is now either banned or permitted only under very stiff constraint. Agro-chemicals other than organo-chlorines are also suspected of causing chronic toxicity when they are ingested and accumulated in the body. The damage no doubt extends to the habitat of animals, plants and fish alike.

All agro-chemicals should be documented on the basis of tests on toxicity and persistence. Among the agro-chemicals now in use, those that have been shown to accumulate in farm crops or soils must be designated as such. It is necessary that control is exercised over their application according to specified methods. Furthermore, chemicals known to pollute water and suspected of being injurious to human health, animals, plants, and fish are also to be designated as such, and their use in a specified area should be controlled. Examples of the persistent agro-chemicals are Lead arsenate; Dieldrin; Aldrin; Terodrin; Endrin; Bezoepin; PCP herbicide; Rotenone; Organic mercury except those for seed dressing; DDT; TEPP; Methyl parathion; Parathion; BHC; Heptachlor; and 2,4,5-T.

4.2.6. Water Storage Fisheries

With the construction of two tidal regulators and acidic water flow check facilities for the strategic basins, there would be a potential of raising the freshwater capture fisheries by using the Bang Nara water storage which is normally maintained at water level of EL+0.4 m with the water surface of 13.9 sq.km being composed of the river channel of about 5.1 sq.km (37 percent) and of the swamp forests of about 8.8 sq.km (63 percent). Water level drawdown for the dry season irrigation would take place during the short period with the low water level limit of EL-0.2 m which has the surface area of 4.8 sq.km occupying only the old channel. It is also noted that the lowest bottom of storage would be around EL-6m.

When the Bang Nara water storage is established, the increases in nutrients caused by anaerobic decomposition, releases from flooded soils and irrigation return flow would enhance the level of fish productivity although there are a few Phytoplankton at present as is explained in para. 3.4.6 of Chapter 3. Review of the storage morphometry, water quality still being slightly acidic and the nutrient increases indicates that the Bang Nara water storage would have a potential for fish production under extensive low input farming. Management of this storage fisheries would be concerned with the stocking with appropriate species at adequate levels. Restocking from time to time would be required if the fisheries are sufficiently productive and economic.

As far as the downstream fish production is concerned, the effect of flow regulation at two tidal regulators would be negligible because the freshwater species along the river estuaries at Narathiwat and Taba are not identified as explained in para. 3.4.6 of Chapter 3. On the other hand, two tidal regulators would cut off the migration of some species from their brackish spawning ground to their fresh growing ground; however, the present situation of such migration would be minor. With this information, DOF, Narathiwat has agreed that fish ladders at two regulators would not be essential, and this could be compensated by artificial stocking of fish fry.

In addition, DOF introduced the fish species relatively resistant to acidic water which are commonly cultured in the pond or river throughout Thailand.

Fish	Estimated Size in cm
1. Climbing Perch (Anabas Testudineus)	20
2. Snake-Heads (Ophiocephalus Spp)	60-80
3. Walking Catfish (Clarias Spp)	20-30
4. Gourami (Trichoguster Spp)	20-30
5. Striped Tiger Nandid (Pristolepis Fasciatus)	20
6. Hoeven's Slender Carp (Leptobarbus Hoeveni)	80
7. Rasbora (Rasbora Spp)	10
8. Feather-Back (Notopterus Spp)	60

DOF, Narathiwat has confirmed that a supply of such seed fish is readily available from two active centers of the Pikulthong near Narathiwat and the DOF freshwater fisheries station at Pattani with no charge on fishermen.

To ensure the economic off-take, the fishery management would be done to control the number of fishermen and the types and sizes of gear which they are able to use and to define, by season and location, the areas where the fishing can be done. The management techniques being inclusive of manipulation of the habits, management of fish population and their food supply need effectively to maintain a steady-state harvest of fish at a level of the optimum productivity of the water storage fisheries. In addition, the introduction of new aquaculture systems such as penculture, net closures or cage culture for rearing of fingerlings and marketable sized fishes would be considered.

It is suggested that the organization of a fisheries cooperative for proper management, maintenance and exploitation of the water storage fisheries, although there is virtually no tradition of such fishing by using the reservoirs in Thailand. Members of such cooperative would be local people and farmers who are living in the vicinity and interested in fishery activities with the fishing fare including the poor marine fishermen along the coastline stretch being suffered from the limited marine resources. It is essential that such cooperative be given the legal coverage as corporate body to make them effective institutions. To this end, DOF will principally have technical backup and monitoring function. It is also necessary to devise the Government policy for the use of Bang Nara water storage for fisheries purpose although there appears to be no conflict of the management interests between RID who is responsible for this water body and DOF for the required extension inputs.

A discussion was made with DOF, Narathiwat on fish escape from the water storage during the temporary inundation around the storage when the tidal gates are fully opened. Because of the anadromous nature of relevant fish against the water velocity of more of less 1m per sec at the regulators, there would be no particular problem on such loss of the freshwater fish production. Taking into account the above mentioned factors, the Bang Nara water storage would provide the fish farming conditions with a potential production level of 100 to 200 kg per ha or 140 to 280 ton per year at its full development taking the lead time of several years being easily obtainable under extensive low input farming.

There is no cultural bias against fish as food, and the proximity of the water storage to the point of major consumption in the Study area would reduce the difficulties of transport and conservation of this highly perishable product. It is considered that part of the fish harvested would be exported to Malaysia after the primary processing by Taba new town traders. At a selling price of ฿18 per kg, this represents a gross annual income of 2,700 per water surface ha, and it is assumed that a fisherman population of approximately 0.5 fisherman per ha or 700 in total would be supported on the substained basis with an additional annual income.

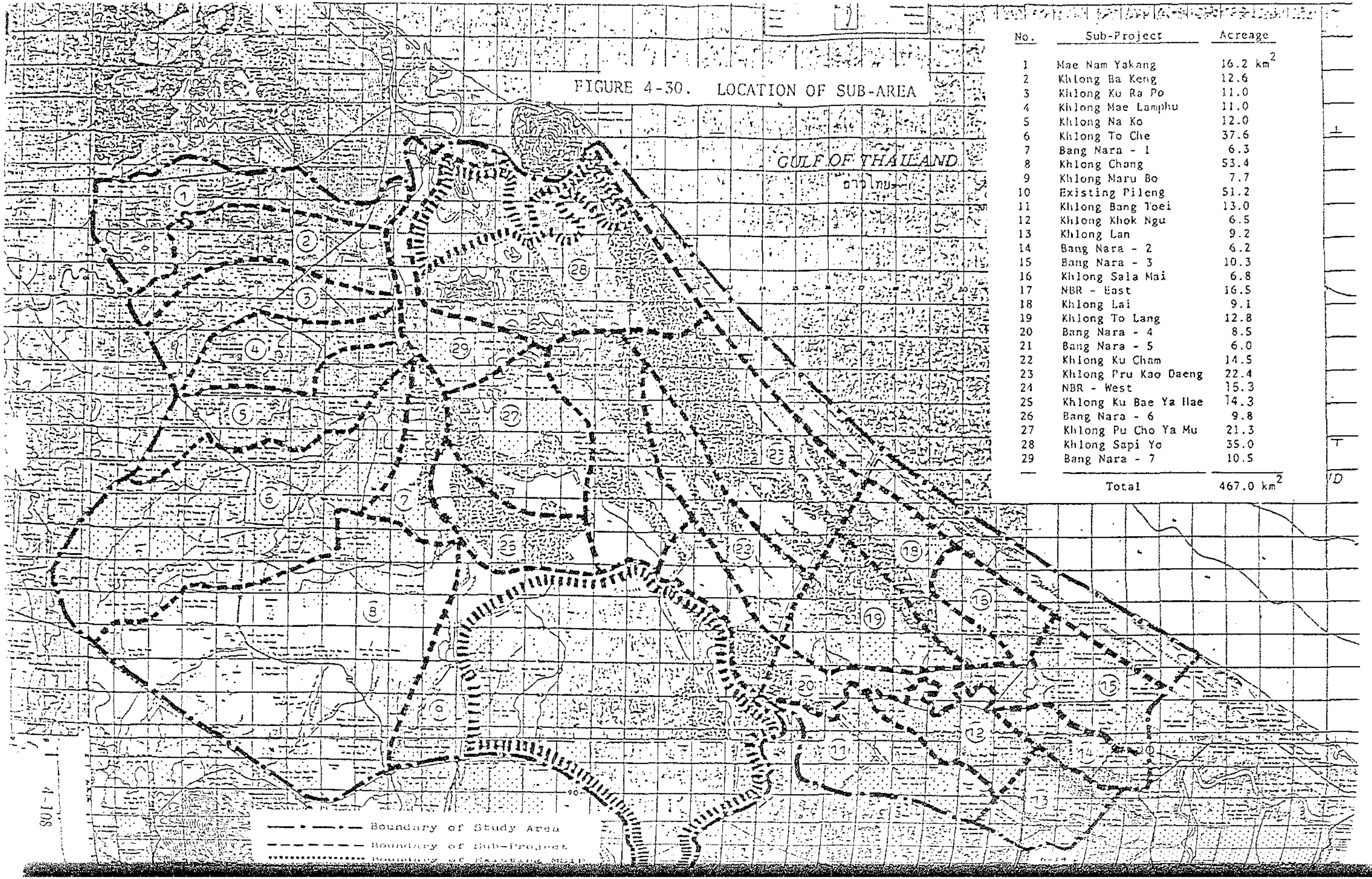
4.3. Irrigation and Drainage Development

4.3.1. Drainage Improvement

(1) Sub-basins Concerned

To establish the optimum development strategy for the Study area, it is necessary to grasp the local features in detail. The Study area, therefore, is divided into 29 sub-areas mainly by the catchment area of tributaries of Mae Nam Bang Nara. Figure 4-30 shows the boundary of the sub-area in the area. The drainage service area by sub-basin is shown in Table VIII-3-6 of Appendix VIII.

FIGURE 4-30. LOCATION OF SUB-AREA



No.	Sub-Project	Acreage
1	Mae Nam Yakang	16.2 km^2
2	Khlong Ba Keng	12.6
3	Khlong Ku Ra Po	11.0
4	Khlong Mae Lamphu	11.0
5	Khlong Na Ko	12.0
6	Khlong To Che	37.6
7	Bang Nara - 1	6.3
8	Khlong Chang	53.4
9	Khlong Maru Bo	7.7
10	Existing Pileng	51.2
11	Khlong Bang Toei	13.0
12	Khlong Khok Ngu	6.5
13	Khlong Lan	9.2
14	Bang Nara - 2	6.2
15	Bang Nara - 3	10.3
16	Khlong Sala Mai	6.8
17	NBR - East	16.5
18	Khlong Lai	9.1
19	Khlong To Lang	12.8
20	Bang Nara - 4	8.5
21	Bang Nara - 5	6.0
22	Khlong Ku Cham	14.5
23	Khlong Pru Kao Daeng	22.4
24	NBR - West	15.3
25	Khlong Ku Bae Ya Hae	14.3
26	Bang Nara - 6	9.8
27	Khlong Pu Cho Ya Mu	21.3
28	Khlong Sapi Yo	35.0
29	Bang Nara - 7	10.5
	Total	467.0 km^2

As discussed in Chapter 3, a part of the Study area is placed under the poor drainage conditions where many damages have been brought by overtopping the flood discharge from Mae Nam Yakang. Those streams and canals in the Study area have too small flow area on the cross-sections to discharge excess water caused by Mae Nam Yakang and heavy rainfall, and some trees also interrupt the smooth flow of flood discharge. On some points at the road-crossing in the Study area, wooden bridges are used. The cross-sectional area is also not enough for flowing down flood discharge during the same period.

It is necessary that the flowing countermeasures would be carried out to improve these streams and canals. The existing streams and canals would be widened and deepened to convey the design flood discharge, and the existing bridges would be reconstructed with an enough flow area. On the other hand, the new drainage canals would be proposed to dissolve existing poor drainage conditions because of geological conditions and no drainage canals in a part of the Study area.

The following streams and canals would be improved:

No.	Sub-Area	Canal	Length Improve (km)	Length New (km)	Catchment Area (sq.km)
1	Mae Nam Yakang	Ban Lo Mo	-	2.5	1.2
3	Kh. Ku Ra Po	Kh. Ku Ra Po	9.0	0.8	26.4
5	Kh. Na Ko	Kh. Na Ko	4.9	-	9.8
6	Kh. To Che	Kh. To Che	5.6	-	39.8
	"	Kh. Lu Bo Manang	10.0	2.5	(21.7)
	"	Kh. Kok Niang	5.5	-	(41.0)
8	Kh. Chang	Kh. Chang	9.8	0.8	90.3
	"	Kh. Ba Nao Du Dong	10.5	-	(65.2)
	"	Kh. Ku Rong Ya Ma	4.7	-	(16.0)
15	Bang Nara-3	Ban Sala Pradu	-	1.1	1.8
16	Kh. Sala Mai	Kh. Sala Mai	5.0	1.7	10.0
	Total		65.0	9.4	179.3

Note: Catchment area shows the drainage area at the most downstream point of a stream.

(2) Drainage Module

(i) Probable Rainfall

From the economic point of view and the field interview of flooding condition, 3-day consecutive probable rainfall with 5-year and 2-year return period would be applied for the drainage planning. The Iwai method is used for probable rainfall analysis. The amount of 3-day consecutive rainfall with 5-year and 2-year return period is calculated at 419.4 mm and 277.4 mm at the Muang station, 459.6 mm and 293.3 mm at the Tak Bai station, 247.1 mm and 127.9 mm at the Rangae station and 406.5 mm and 232.3 mm at the Yingo station, respectively. Other stations do not have long-term period rainfall records for the probability analysis. (refer to Tables VIII-3-1 to -4 in Appendix VIII)

(ii) Areal Rainfall

To calculate average rainfall of the Area, areal ratio by the Thiessen method is 0.13 for Muang station, 0.19 for Tak Bai station, 0.57 for Rangae station and 0.11 for Yingo station when the above four observatories are effective. The weighted average 3-day consecutive rainfall is calculated at 327.4 mm for 5-year return period and 190.2 mm for 2-year return period.

(iii) Rainfall Intensity

According to the field investigations and the field interviews, run-off arrival time after the beginning of rainfall is usually within one day in the tributaries of the area. On the other hand, based on the water level record and rainfall in the Yakang river basin, its duration is within one to two days depending upon the rainfall pattern and intensity. For the design of the tributaries to be improved, the run-off arrival time of 8 hours is assumed to calculate the design rainfall intensity. The following equation would be used for calculation of the rainfall intensity.

$$rt = \frac{R24}{24} \left(\frac{24}{T} \right)^{0.666}$$

where, rt : rainfall intensity in mm/hr

R24 : 24-hr rainfall, (327.4 mm /3day = 109.1 mm/day of 5-year return period) and (190.2 mm/3 day = 63.4 mm /day of 2-year return period)

T : run-off arrival time in hrs

therefore,

rt (5-year return period) = 9.6 mm/hr

rt (2-year return period) = 5.6 mm/hr

(iv) Run-off Coefficient

Run-off coefficient is determined depending on the vegetation and geographic condition of the drainage area. Vegetation of the drainage area in and around the Area is in a good condition covering with many trees or grasses. In the plain area, many rubber plantation areas are found and paddy fields have a sufficient rainfall storage capacity during the rainy season.

Topographically, the drainage area is moderately sloped at about 1:600 and is partly rolling and undulating. Many tributaries have small mountainous area which is steeply sloped and well vegetated. However, ratio of the steeply sloped area to the total drainage area is about 10 percent and ratio of the mountainous area in the total drainage area varies from 10 to 40 percent. An overall run-off coefficient of 0.4 would be used taking into account the above conditions.

(v) Drainage Module

The drainage module (q) is calculated by using the rational formula :

$$q = f.rt.A/3.6$$

where q : run-off discharge in cu.m/sec or lit/sec/ha

f : run-off coefficient (0.4)

rt : average design rainfall intensity (9.6 mm/hr of 5-year return period and 5.6 mm/hr of 2-year return period)

A : drainage area in sq.km

Therefore, drainage module on 5-year return period and 2-year return period are 0.0107 cu.m per sec per ha (10.7 litre per sec per ha) and 0.0622 cu.m per sec per ha (6.2 litre per sec per ha), respectively.

(vi) Areal Reduction of Drainage Module

In the tropical monsoon zone, the rainfall distribution is, as well known, not uniform in the drainage area, because the high rainfall intensity zone is generally limited and is moving. It is necessary, therefore, that the above drainage module should be revised depending upon a scale of the drainage area. For assuming an areal rainfall, the Hortor equation would be applied to calculate the decrease ratio by the scale of the drainage area:

$$R = Ro\ e^{-KA^{n}}$$

where
R : areal rainfall in mm
Ro : rainfall in mm
K : constant (0.1)
A : drainage area in sq.km
n : constant (0.2)

Table 4-10 Drainage Module

** 5-year Return Period **

Drainage Area		Areal	Drainage Module	
in ha	in rai	rainfall	lps/ha	lps/rai
upto 250	upto 1560	109.1 (mm)	10.6	1.7
250 to 500	1560 to 3120	96.5	9.2	1.5
500 to 1000	3120 to 6250	94.6	9.1	1.5
1000 to 2000	6250 to 12500	92.4	8.8	1.4
2000 to 3000	12500 to 18750	90.9	8.7	1.4
3000 to 5000	18750 to 31250	89.0	8.5	1.4
5000 to 10000	31250 to 62500	86.2	8.2	1.3

** 2-year Return Period **

Drainage Area		Areal	Drainage Module	
in ha	in rai	rainfall	lps/ha	lps/rai
upto 250	upto 1560	63.4 (mm)	6.2	1.0
250 to 500	1560 to 3120	56.0	5.4	0.9
500 to 1000	3120 to 6250	54.8	5.3	0.9
1000 to 2000	6250 to 12500	53.6	5.2	0.8
2000 to 3000	12500 to 18750	52.8	5.1	0.8
3000 to 5000	18750 to 31250	51.6	5.0	0.8
5000 to 10000	31250 to 62500	50.0	4.8	0.8

(3) Allowable Depth and Duration of Standing Water

During the flood period, flood damage of crops would occur according to a degree of water depth and standing duration on a farm land. In the Area, paddy is a main crop during the main season, therefore, the allowable water depth and duration of standing water on a field are determined by the grass height of paddy and occurrence time of flood. According to the experimental results of flood damage, when paddy is submerged during a period of more than 2 days, flood damage would be serious (refer to Table VIII-3-5 and Figure VIII-3-5 and Figure VIII-3-1 in Appendix VIII). When many floods usually occur in December, the height of paddy would reach up to 50 cm. To reduce flood damage, 10 cm of leaves top should be above the standing water, therefore, the allowable depth of standing water for the paddy is taken at 40 cm.

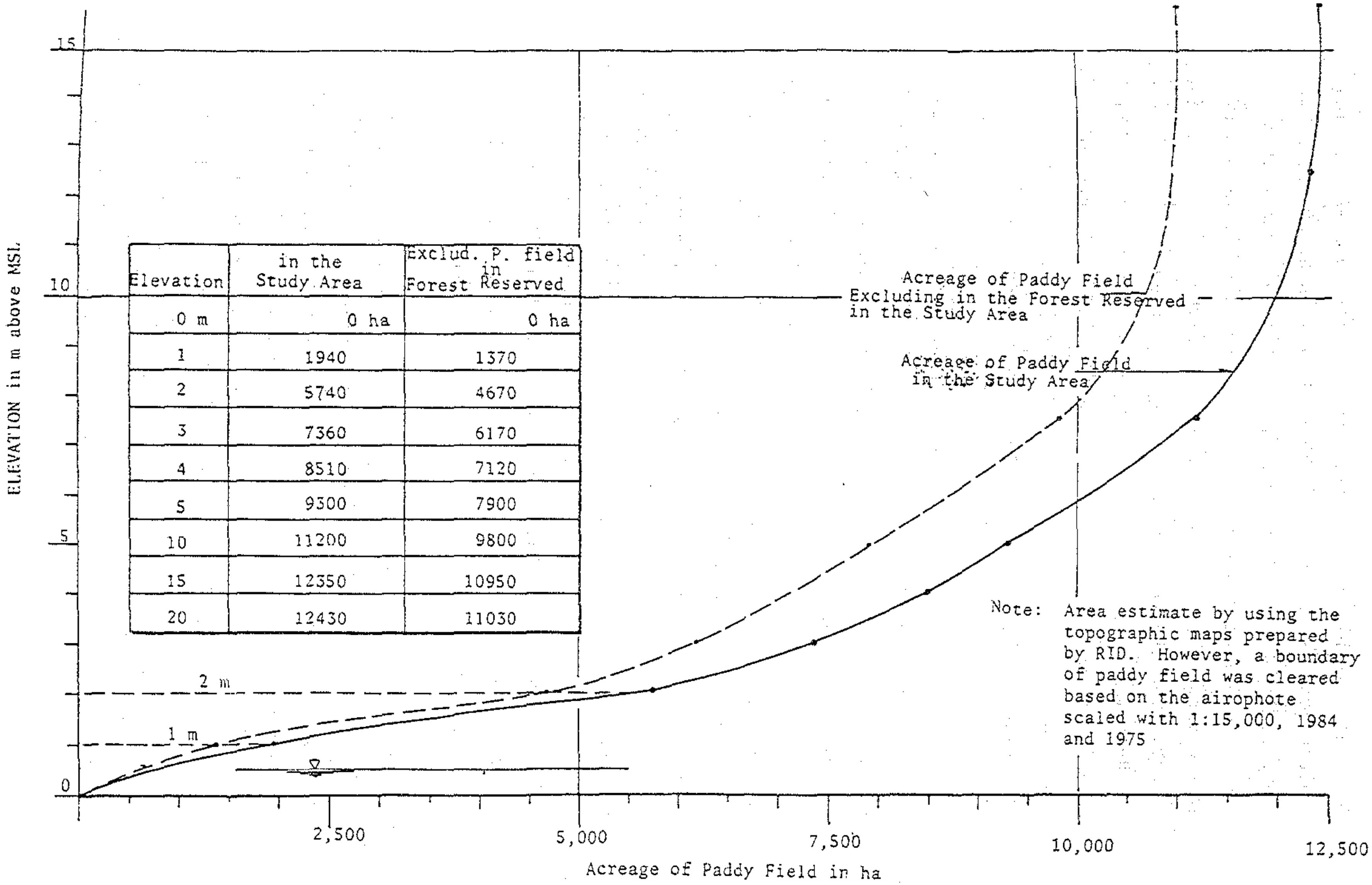
4.3.2 Irrigation Development

(1) Topographic Conditions

The Study area is roughly divided into three blocks, (1) the western block of Mae Nam Bang Nara, (2) the upper block which is bounded by Mae Nam Bang Nara, the Nam Baeng canal and the coastal line, and (3) the lower block.

The western block consists of three parts, (a) the upper paddy cultivation zone, (b) the rubber plantation zone and (c) the Pileng project area. The paddy cultivation zone is mainly located in the northern part of the block. An elevation of this zone is ranging from EL+0.5 to 20 m. The zone has a moderate slope of 1:600 towards east or Mae ßNam Bang Nara. Almost half of the area is occupied by the scattered paddy field of 6,150 ha in total which is surrounded by the rubber plantation area. The contour line of EL+1 m is drawn about 1 km far from Mae Nam Bang Nara. (refer to Figure 4-31 in this para. and Figure VIII-2-8 in Appendix VIII)

FIGURE 4-31 H-A OF PRESENT PADDY FIELD IN STUDY AREA



Elevation	in the Study Area	Exclud. P. field in Forest Reserved
0 m	0 ha	0 ha
1	1940	1370
2	5740	4670
3	7360	6170
4	8510	7120
5	9300	7900
10	11200	9800
15	12350	10950
20	12430	11030

Note: Area estimate by using the topographic maps prepared by RID. However, a boundary of paddy field was cleared based on the airophote scaled with 1:15,000, 1984 and 1975

The wide area between the paddy cultivation zone and the Pileng project area is called as "Rubber plantation area" which has a slope of 1:600 in average and an elevation of from EL+0.5 to 20m. The Pileng project area is located at the southern part of the Block which is in the boundary of the Laem Nam Reserved Forest. The project area of Pileng is, however, excluded from the Reserved Forest area under RFD, and the one-third of its area is below EL +1m. The area inclines with a slope of about 1:600 to 1:700 towards south-east on Mae Nam Bang Nara, and an elevation of the area is ranging from zero to +8m.

The upper block is bounded by Mae Nam Bang Nara in west and north, by the Nam Baeng canal in south and by a coastal line of the Gulf of Thailand in east. The block consists of an alluvium plain and beach-sand dune. The plain area with the maximum width of about 6 km is located along Mae Nam Bang Nara and is below EL+1 m. Almost all part of the area, however, is reserved as a national forest area. On the other hand, the eastern part of the block is occupied by the beach-sand dune of EL+2 to 8 m. The boundary between the alluvium plain and the beach-sand dune is clearly recognized. The beach-sand dune is composed of three lines in parallel with the coastal line. The rainfed paddy fields with 1 km width and with a belt shape are sandwiched by beach-sand dunes. The total acreage of the existing paddy field is measured at about 2,800 ha.

One SSIP project named as Khlong Pru Kap Daeng was recently implemented in the rainfed paddy area, which constructed a drainage canal with a tail gate near the confluence point to the Nam Baeng canal. The farmer, however, could not well operate the gate, and the drainage canal brings an over-drain effect. Consequently, the paddy field has became a wild fallow area. In the northern part of the block, the Klaiban irrigation and drainage project, one of the medium scale irrigation projects under RID, was implemented.

The southern part of the Study area which is called as "lower block" is located at the south of the upper block as mentioned before. The boundaries of the lower block are the Nam Baeng canal at north, the edge of the To Daeng swamp at east, the ARD road from Ban Khok It to Ban Sala Pradu via the proposed Lower Tidal Regulator at south and the coastal line of the Gulf of Thailand at north. The block area is extending on the both banks of Mae Nam Bang Nara. The block shows the similar topographical features of the former upper block. The acreage of 3,480 ha is cultivated as a rainfed paddy field, and lower hilly areas of the beach-sand dune are used as coconuts field and the residential area to avoid inundation or standing water during the rainy season.

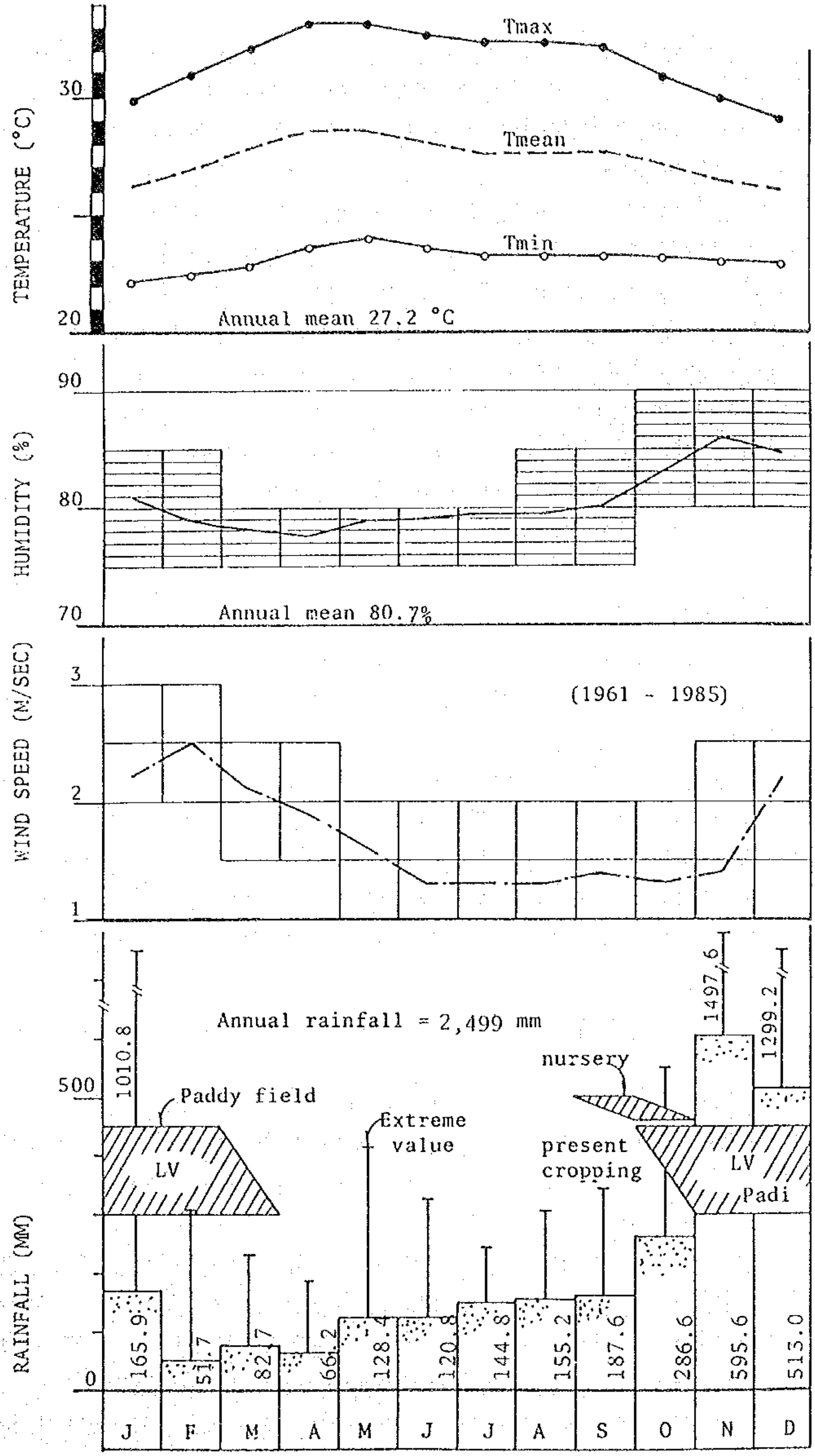
(ii) Rivers and Streams

A few rivers and streams which do not dry up the off-season are found in the Study area. Existing small stream or Khlong, however, are not yet developed as a drainage canal in the area. Since in the western block, the steeply sloped catchment area is included in the drainage area of the streams, the high runoff easily occurs during the rainy season. (For more information regarding to this item , refer to Appendix II)

(iii) Weather Condition

The Study area is in a favourable weather condition for various farming. The values of temperature, wind velocity and humidity vary within the moderate range. The rainfall, however, is only one disadvantageous point among various weather items, that is, the amount of about 60 percent of annual rainfall is observed in October to December (refer to Figure 4-32). When various facilities on the irrigation and drainage system are introduced in the area to solve such disadvantageous conditions, the inhabitants in the area would be able to enjoy farm benefits.

FIGURE 4-32 CLIMATICAL CONDITIONS (NARATHIWAT, 1952-1985)



Source: Meteorological Department, MOC

(2) Irrigation Water Requirement

(i) Evapotranspiration (ETo)

a) Basic Data

The major meteorological data to calculate an amount of evapotranspiration have been collected from the Narathiwat meteorological observatory as a representative station of the Study area. Since sunshine hour data, however, are not available during 1981 to 1984, mean values of the station from 1950 to 1980 are applied.

b) Equation Employed

The Modified Penman method is used to calculate evapotranspiration rate by using the former basic data. The reports titled as "Potential Evapotranspiration and Crop Coefficient for Rice in Thailand" by Mr. Direk Tongaram, O & M Div., RID, 1985 recommends that the Penman method are most suitable to estimate evapotranspiration rate in Thailand through the various actual observation and analysis.

c) Calculated ETo

The monthly evapotranspiration rates are calculated and shown as follows:

(Unit: mm)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
124	134	155	153	133	120	121	121	117	112	96	105

The amount of annual evapotranspiration is 1,491 mm (refer to Table VIII-2-12 in Appendix VIII).

d) Crop Coefficient (kc value)

The following crop coefficients (kc value) of the crops would be used for the irrigation planning. The kc value for the paddy cultivation is determined based on the reports of "Potential Evapotranspiration and Crop Coefficient for Rice in Thailand" written by Mr. Direk Tongagram, O & M Div., 1985 and for other crops, the values from "FAO Irrigation and Drainage Paper #24", 1977 are used. The kc value of paddy ranges from 0.98 to 1.27. The following kc values for other diversified crops' cultivation are applied for the irrigation planning.

	kc value by growing stage		
Crop	beginning	peak	last
Sweet Corn	0.41	1.05	0.95
Mungbean	0.41	0.96	0.85
Groundnuts	0.42	1.06	0.55
Vegetables*	0.39	1.17	0.60

Note: kc value of tomato is used as representative of vegetables. (For further details, refer to Figure VIII-2-9 in Appendix VIII)

(ii) Percolation Rate

Percolation rate mainly depends upon the soil texture of a field. Soil texture of a paddy field in the Area is clay to clay loam which shows general percolation rate of 0.5 to 1.5 mm per day. The other factors such as seepage loss from paddy dikes, land slope, density of drainage canal and groundwater table would also be considered. The Study area is classified into the flat plain, and the density of drainage canal is low. Seepage water, therefore, would be smaller.

According to the observation of percolation rate by soil type in the Study area, the weighted average of percolation rate of 1 mm per day has been obtained. Percolation rate of 1.0 mm per day including seepage is applied to estimate irrigation water requirement. (refer to Table VIII-2-13 in Appendix VIII)

(iii) Diversion Water Requirement

a) Diversion Water Requirement for Irrigation Facilities

- Unit Water Requirement for Design of On-Farm Facilities

  Max. water requirement (MWR) on growing period

    Irrigation requirement 6.2 mm/day (=4.4 x 1.18 + 1)

    MWRa = 6.2 x 10 /(86,400 x 0.6) = 1.2 lit/sec/ha

  Max. water requirement on Preparatory Works

Water depth of preparatory works	220 mm
First application	85 mm
Second application	85 mm
Last application	50 mm

    MWRb = 220 x 10 /(86,400 x 45 x 0.6) = 1.1 lit/sec/ha

- Unit Water Requirement for Design of Canal

  The calculation procedures are same as above.

    MRWa = 6.2 x 10/(86,400 x 0.54) = 1.3 lit/sec/ha

    MRWb = 220 x 10/(86,400 x 45 x 0.54) = 1.1 lit/sec/ha

Consequently, for design of the on-farm facilities and the main or lateral canals, diversion water requirement of 1.2 and 1.3 litre per sec per ha would be applied, respectively.

b) Water Requirement for Rotational Unit

The 7-day rotational irrigation system would be introduced to make simple and easy operation of the on-farm facilities by WUG. In this case, the flow capacity of 30 litre per sec of a farm ditch would be necessary for a 25 ha rotational unit and 24 litre per sec for a 20 ha rotational unit.

7 days x 1.2 lit/sec/ha x 25 ha / 7 days = 30 lit/sec

7 days x 1.2 lit/sec/ha x 20 ha / 7 days = 24 lit/sec

(3) Water Sources

There are three kinds of water sources in the Study area under the proposed irrigation scheme, (1) Mae Nam Yakang and other tributaries of Mae Nam Bang Nara, (2) groundwater, and (3) return flow from the paddy field under irrigation system.

(i) Surface Water

Mae Nam Yakang which is the largest water source for the Study area and the river is not dried up throughout a year. Monthly discharge of the river is largely fluctuated according to the season. The amount of about 60 percent of the annual discharge is calculated during five months of the main-season from September to January. The average annual discharge is computed at 1,130 MCM. The mean discharge of the main-and off-seasons, and annual mean are calculated at about 60, 15 and 36 cu.m per sec, respectively.

The other tributaries of Mae Nam Bang Nara have smaller amount of discharge than Mae Nam Yakang discharge. The amounts of seasonal mean discharge during the above period also are calculated at 76 percent or 40 cu.m per sec in the main-season, 24 percent or 9 cu.m per sec during the off-season, and 22.2 cu.m per sec throughout a year, respectively. The most streams or rivers are usually dried up during two months from March to April. The probable droughty discharge with 2-yr, 5-yr, 10-yr return period of Mae Nam Yakang are computed at 6.9, 5.3 and 4.8 cu.m per sec, respectively. (For further details, refer to 3.34 (2) of Chapter 3.)

(ii) Groundwater

a) In Low-lying Area near Narathiwat

The area is geographically located at the flood plain or the low-lying land such as old swamp. Since the Monadnock such as Khao Ya Bi and Khao Kong is found around the area, it is possible to have Colluvial soil or Granite in the shallow layers. Therefore, it is supposed to have Chao Phraya aquifer, Colluvial aquifer and Granitic aquifer. The stable amount of groundwater from this Granitic aquifer would not be expected, because groundwater is kept in weathered zone, faults and etc. of the aquifer. The yield of existing deep wells is less than only 40 lit per min.

On the other hand, the mean yield of existing five wells in other two aquifers are measured at about 220 lit per min in average.

Aquifer	Existing Deep Well	Depth (m)	Draw-down (m)	Yield (lit/min)
Chao Phraya	MD-3	27.45	13.73	151.4
	MD-4	26.53	18.30	113.6
	MD-101	33.50	-	302.8
Colluvial	MD-104	16.75	2.44	302.8
Average				217.6

b) In Low-Lying Area near Rangae

The area is also geographically located at the flood plain. The Colluvial aquifer mainly exists in the area. The present condition of existing deep wells from the aquifer is shown as follows:

Aquifer	Existing Deep Well	Depth (m)	Draw-down (m)	Yield (lit/min)
Colluvial	YD-4	36.60	8.20	37.85
	YD-5	10.70	5.50	37.85
	YD-6	21.35	1.80	37.85
	YD-101	19.80	15.20	75.70
	MD-104	16.75	2.44	302.80
	MD-9	25.90	1.30	199.90
Average				115.3

According to the above data, the mean yield of a deep well is estimated at 115 lit per min or 6.9 cu.m per hr. (For further details, refer to para. 3.3.4 (3) in Chapter 3).

c) In Low-Lying Area near Tak Bai

The area is located at a beach ridge or an old lagoon including the Chao Phraya aquifer and the beach-sand aquifer. Groundwater in the beach-sand aquifer is unconfined above the saline water, therefore, much amount of groundwater to be pumped up would affect other existing wells in terms of increasing salinity. On the other hand, the Chao Phraya aquifer has already salinity, and EC value of groundwater in existing wells is ranging from 2,000 to 3,000 micromhos/cm. (Refer to para. 3.3.4 (3) in Chapter 3.)

(iii) Irrigation Return Flow

When the irrigation system is introduced, many water losses are found. The losses would flow into the drainage canal, however, this water usually can not re-use for the area because of topographic condition that the catch-canal is located at the lowest portion. In the Study area, Mae Nam Bang Nara is located at the lowest portion and the pumping facilities would be required. Therefore, it is easy to re-use water from the Bang Nara storage. From the viewpoint of the total losses of 43 percent for paddy cultivation, return flow rate of 30 percent to the amount of irrigation water for paddy cultivation would be considered possible. (Refer to para. 4.3.2 (3) of this Chapter.)

(4) Gravity Irrigation Scheme

(i) Water Source

The gravity irrigation scheme is introduced for the paddy fields near Ban Kampong Ni Bong, Amphoe Rangae, because Khlong Maru Bo is not dried up during the dry season. The specific droughty discharge of Mae Nam Yakang is used to estimate the droughty discharge because of the similar features such as vegetation, topographic condition and etc. of the both catchment areas. The estimated probable droughty discharge at existing weir constructed by ARD at Ban Ke Ta Mong is 440 lit per sec (5.3 cu.m/sec / 724 sq.km x 60 sq.km = 0.439 cu.m/sec). Further detailed information are presented in para. 3.3.4 (2) in Chapter 3.

(ii) Irrigation Service Area

The existing paddy field of about 600 ha is extending in the right bank of Khlong Maru Bo and the proposed acreage under the gravity irrigation system is 180 ha. The amount of water requirement is estimated considering the above both acreages. The crop intensity of 125 percent and upland crops during the off-season would be applied, therefore, the amount of about 270 lit per sec for upland crop can supply from the said Khlong according to the following calculations:

- Total irrigation acreage (600+180) x 0.25 = 195 ha
- Evapotranspiration at May 4.3 mm/day
- Crop factor (the max. value is applied) 1.17
- Total irrigation efficiency 0.43
- Unit diversion water requirement:
  4.3 x 1.17 x 10 / 86,400 / 0.43 = 1.35 lit/sec/ha
- Total water requirement, 195 x 1.35 = 263 lit/sec

(iii) Irrigation System

The existing weir constructed by ARD is located 3.5 km far from the proposed irrigation area by gravity. The existing intake is 1 km downstream from the weir. The river bed is lower than the invert of existing intake, and the existing connecting canals are sedimented because of poor maintenance. In order to boost agricultural production in the area, an intake facility with gates at the left bank of the weir, a concrete-paved feeder canal from the weir, rehabilitation of existing irrigation canals and its appurtenant structures such as diversion boxes and crossing structures would be planned. (Refer to para. 5.4 in Chapter 5.)

(5) Pumping Irrigation Scheme

(i) Irrigation Service Area

It has been understood that there would be a contrary in diverting water of the Bang Nara storage situated at the bottom of the Study area for irrigation of the surrounding high-lying areas in terms of storage's low water level and small capacity.

Taking into account an impounding water level of the storage in view of the lowest gate top of EL +1.1 m at UTR as well as a probable drawdown of the storage water level during the critical dry period due to rather small storage capacity, there would be no potential to perform the gravity irrigation. The proposed irrigation scheme from the Bang Nara water storage, therefore, would depend upon the pumping irrigation as a whole.

According to the results of water balance simulation studies, the total irrigation service acreage is estimated at 9,980 ha (about 62,300 rai) which includes 180 ha of paddy field under gravity irrigation system. The breakdown of the acreage by sub-basin is presented in Table VIII-2-10 of Appendix VIII.

(ii) WUG Pumping Scheme

Existing paddy field below EL +2 m on an average which is distributed around the Bang Nara water storage with an irrigable area of 3,870 ha would be irrigated by portable pumps utilizing existing small streams and drains, and the proposed farm drains as on-farm facilities, reversely from the water storage. A self-priming centrifugal pump coupled with gasoline engine with a diameter of 100 mm, a total head of five meters, an engine capacity of 7 Hp, a lifted capacity of 1.65 cu.m per min and a weight of about 100 kg would irrigate about 20 ha of a paddy field.

As soon as the Bang Nara water storage is established, the above mentioned irrigable area would be in a possible situation to be served by a series of portable pumps when the WUGs are properly organized and the on-farm work including the pump procurement is provided under the Government technical and financial assistance. This arrangement would correspond to the planning and formulation of a quick-yielding project.

(iii) RID Pumping Scheme

Existing paddy field above EL +2 m would be irrigated by fixed type pumps with some improvement of existing small tributaries and drains from the Bang Nara water storage. The preliminary layout of fixed pump scheme is outlined below:

No.	Subproject	Service Area (ha)	Diversion 1/ Channel (km)	Pump Max.Q (cu.m/sec)	Pump No. of Units	Main and Lateral Canal (km)
1.	Pu Ta 3/	230	-	0.32	2	5.1
2.	Khao Kong 3/	560	-	0.77	2	16.9
3.	Du Song	880	3.1	1.22	2	20.0
4.	Tan Yong Mat 3/	1,090	-	1.50	3	18.9
5.	Khok Ti Te	1,120	3.5	1.54	4	32.7
6.	Maru Bo	470	4.6	0.65	2	9.4
7.	Salai Mai	490	1.3	0.68	2	11.8
8.	Ko Sawat	520	-	0.72	2	15.0
9.	Khru Kap Daeng	380	-	0.52	2	14.3
10.	Ku Cham	190	-	0.26	2	7.8
	Total	5,930	12.5	8.18	23	151.9

1/ ... Deepening of the Bang Nara tributaries from the Bang Nara water storage to the pumping plants.
2/ ... Inclined mixed or axial flow type.
3/ ... From Mae Nam Yakang.

A study in each irrigable area indicates that 2 sets of inclined vertical mixed flow pumps with a diameter of 300 to 600 mm, a total head of 5 to 21.5 m, motor capacity of 18.5 to 160 kw and a capacity of 7.8 to 36.6 cu.m per min per set would be provided. Following this, the main and lateral canals would be provided up to the outlet into each terminal service unit with a standard size of 20 ha. The total number of RID pumping stations which would irrigate 5,930 ha (37,060 rai) of the paddy field is counted at ten in the Study area. The three stations named as Pu Ta, Khao Kong and Tan Yong Mat would take irrigation water directly from Mae Nam Yakang. The total amount of water to be lifted from Mae Nam Yakang is calculated at 2.59 cu.m per sec in maximum.

(6) On-Farm Scheme

(i) Development Method

After construction of the Bang Nara water storage, on-farm development would be implemented as soon as possible in the proposed irrigation area to get quick-yield of irrigation scheme.

There are two kinds of on-farm development in Thailand such as "intensive" and "extensive". The intensive on-farm development includes land levelling and reparcelling of farm plots as well as on-farm facilities such as farm ditches, farm drains, farm road and related structures. This development has remarkable features that all commanded areas are perfectly developed, and unequality on water distribution would not be found under good water management. The density of on-farm facilities is high, and the investment cost is higher.

Another development method has opposite features against the former one. The low investment cost, quick-yield, low O & M cost would be expected. Education of farmers under the proposed WUG is important for good water management, part of which would be carried out at the proposed demonstration farms in the Study area.

In consideration of the present situation of the irrigable area, extensive development with good water management is recommendable because of the traditional land inheritance system and lower investment cost.

(ii) Proposed Size of Service Unit

The size of a service unit is proposed taking into account the number of farmers in a Muban, a size of a plot and a farm size. In connection with the traditional land inheritance system, the farm size is getting smaller generation by generation. At present, a farm size of a paddy field surveyed is 5 to 7 rai per paddy farmer and 3 to 4 rai per mixed farmer. Those farm size is rather smaller than that of the other area in Thailand.

A water users' group (WUG) would be organized in each Muban in order to make good water management. Muban in the Study area consists of 20 to 30 farm households, therefore, it is recommended that a size of WUG is 25 ha or about 150 rai in average. To determine the standard size of a service unit, sample layout of the on-farm facilities has been carried out on the topographic maps surveyed by RID in 1986, considering the existing road, drain, village and present land use. The average size of a service unit is 20 ha (130 rai) which are ranging from 13 ha (80 rai) to 26 ha (160 rai). (Refer to para. 5.5 in Chapter 5.)

4.3.3 Alternative Plans of Irrigation Development

(1) Yakang Collecting Intake

When enough water is taken from Mae Nam Yakang, the following alternative irrigation plan where Mae Nam Yakang is closely running along the northwest boundary or the highest portion of the Area would be considered. A collecting conduit (gallery) is constructed in order to avoid flow area reductions of the Yakang river, and an intake facility is planned at Ban Cha Nu Rang Bu Ro, Amphoe Rangae or 1.5 km upstream of the railway bridge over Mae Nam Yakang. The cross-section of Mae Nam Yakang at the X73 water level gauging station has been applied for the basic design. Tentative cost of ฿250 x 10^6 at 1985 price would be necessary for construction and this plan is much costly. (Refer to Table VIII-2-17 in Appendix VIII)

(2) Groundwater Development

According to the estimation of specific yield for the deep well, the water amount of 170 lit per min would be expected to be taken from a proposed deep well with an influence radius of 600 to 700 m. When the irrigation facilities of deep well, submerged pump and farm ditches are provided, the irrigation area of about 1.5 ha or 10 rai with 12-hour pump operation would be served by groundwater.

$$2.8 \text{ lit/sec} \div 0.92 \text{ lit/sec} \times (24 \text{ hrs}/12 \text{ hrs}) = 1.5 \text{ ha}$$

The EIRR of 5.4 percent has been examined based on the investment cost of ฿277,000 including 20 percent of contingency and the benefit of ฿45,000 from upland crops of mungbean of 0.5 ha, groundnuts of 0.5 ha, tomato of 0.25 ha and chili of 0.25 ha, which would not be feasible for the farmers. (For further details of construction cost, refer to para. II-3-4 in Appendix II.)

4.4. Integrated Agricultural Development

4.4.1 Proposed Cropping Pattern

(1) Crop Selection

In preparing the proposed cropping pattern, the growing season for different crops needs to be carefully examined. Harvesting and planting operations are properly designed to meet the biological requirements of the rotational crops. The right timing of field preparation, planting and pest control operations often determines the crop yields and general success of the agricultural development. The vegetation cycle of a crop is also given to fit into the climatic pattern of the Project area. The proposed cropping pattern would include long and short vegetation cycle crops. Careful selection of the varieties and strains is undertaken in order to pick out most suitable ones. However, there would be always a complication between the crops for suitable planting seasons. Substitute and complementary crops would often be included.

It is noted that the crop rotation is essential for effectively controlling the soil productivity. Alternating appropriate crops in accordance with a pre-established schedule helps to keep the soil in good biological conditions, to control the erosion risk, to increase the soil's moisture-holding capacity, to provide an adequate supply of the organic matters, to prevent the unbalanced depletion of plant nutrients, and to counteract the possible development of the toxic substances.

In irrigated farming of the Project area, crop rotation helps to make the most effective use of the available water resources. The overall water consumption would be more evenly spread over the whole year in accordance with the requirements of crops in the rotation. The higher intensity of the cropping pattern can be achieved by an almost continuous occupation of the land. The effective irrigation of cultivated land may last an average of 9 to 10 months a year. Suitable rotations would serve to generalize appropriate cropping on the area. When an adequate control of water supply is available and there is no handicapping agronomic factors, the planting period would be advanced well before the rainy season and thus allow a substantial saving of the irrigation water.

Taking into account the above factors, the crops to be introduced in the Project area have been selected. These are paddy, mungbeans, groundnut,sweet corn, vegetables, forage crops and tree fruits. Of these crops, the main-season paddy has been selected for the following reasons:

a) the main diet of the people;
b) the crop much familiar with the farmers;
c) the main crop of existing farm;
d) the main item of farm products; and
e) the solution of regional shortage in rice supply.

In the area with deeper and sandy loam soils in the paddy field, a reasonable expansion in the area of groundnut and sweet corn would be expected when the supply of good quality seed at a price acceptable to farmers is improved. Given better and more stable prices and a change in farmers attitudes, mungbeans appear the only crop with the definite prospect for expansion. It is fairly easy to grow and is already accepted by the local farmers. When a variety which is proved to be more suited to the climate and resistant to water and humidity induced diseases is found, a further expansion could be expected.

Various vegetables would grow reasonably well in the paddy field with irrigation, and include cucumber, tomatoes, chili, green leafy vegetables and so forth. These would be introduced with a bright future.

Long Kong is one of the major tree fruits grown in the Project area. Present supply of Long Kong is insufficient to meet the local demand, and quantities of fruits are also sold to the large potential markets in Hadyai and Bangkok.

In addition to the above-said main crops, it is desirable that the forage crops are introduced to maintain the soil fertility and improve the soil structure besides the supply of animal feed. In the development plan, the forage crops are proposed to plant in the area which is not so suitable for paddy cultivation due mainly to the soil characters in the paddy field of EL 2 to 13 m (Refer to V-2 of Appendix V).

From the viewpoint of the above, main-season paddy, mungbeans, groundnut, sweet corn, vegetables such as tomatoes and chili as representive ones, tree fruits like Long Kong, and forage crops such as torpedo and para grass have been selected for the Project development.

Meantime, in reply to the RID's request, possibility on oil palm plantation in the Study area has been examined:

1) There is no commercial cropping of oil palm in the Study area. In the Pileng land settlement scheme, oil palms are experimentally planted in the median strip of the main road with drains on both sides. Level of water in drains varies from 50 cm below soil surface to more.

2) In the Study area, annual rainfall exceeds the required minimum of 2,000 mm but the distribution is not so even with a low rainfall in the period of February to April. This would result in moisture stress affecting bud initiation, sex ratios and hence yields, particularly the peak monthly yields. As for soils, with the exception of acid sulphate soils, the chemical or nutrient status would not pose any real problems. In addition, periodic but

short-term flooding could be tolerable increasing the age of oil palms. Irrigation would be usually impracticable except for maintenance of the water level at suitable depth below soil surface.

3) Particularly, the minimum area for oil palm development on a commercial scale would be determined in due consideration of the efficient process of the fresh fruit bunches (FFB). It is said that the smallest mill able to provide the reasonable efficiency would be 18 ton FFB per hour. Assuming an annual yield of 20 ton FFB per ha, a peak monthly yield equivalent to 16 percent of this, and factory operation is 500 hours per month, the area which could be handled would be 2,800 ha or 17,500 rai. If the average yield is 25 ton per ha, the area would be 2,250 ha or 14,063 rai. Any development less than this area would result in loss of efficiency and lower returns to the oil palm project.

4) Further, fresh fruit bunches would be processed within 24 hours of harvest to avoid the build up free fatty acid which lowers oil quality. This means that the oil palm planted area would be largely contiguous to keep the costs of road and connection down with a radius of 30 km from the proposed mill.

5) GRBDS has recommended so-called "Nucleus Estate" as being most appropriate which involves a central estate to be operated by a private company or a Government enterprise and also by surrounding smallholders plantations. Usually 1,500 ha would be in the nucleus estate which is responsible for its own plantation and the factory; therefore, the remaining would comprise existing smallholding paddy and rubber farmers. At this stage, it is assumed that there would be a difficulty in land acquisition from existing smallholding farmers for the nucleus estate, apart from the Forest Reserves.

6) In implementing such oil palm development project, the organizational structure for support services is required. Presently, there is no agency with the overall responsibility for the promotion of oil palm development.

7) Reference is made to V-2 of Appendix V which introduces some data on the suitability of oil palm plantation in the Study area. These data show that the low-lying coastal plain as is seen in the Study area would not be suitable taking into account the climatic and soil conditions.

(2) Cropping Pattern

The basic concept for agricultural development in the Project area is to increase the production of the main-season paddy and field crop and vegetables production in such manner that even though the area is not so wide, double cropping would be practised under the proper irrigation and drainage scheme.

Cropping pattern has been given taking into consideration climate, irrigation water supplied from Bang Nara water storage and other rivers, agronomic characteristics, etc. In view of the current Government policy to reduce the rice production due to the depression of its export and the unfavorable farm gate price, the production of off-season paddy has not been incorporated into a plan. The proposed cropping pattern is illustrated in Figures 4-33 and 34.

With regard to the main-season paddy, the climatic condition in the Project area is favourable for its cultivation in view of high temperature, high relative humidity and sufficient sunshine hours. Since there is no limiting or adverse factor for germination of seed, seeding of paddy would be practised at any time. However, setting of harvested period would be considered so as to exclude the period with high rainfall intensity and long rainy days for the smooth operation of harvest and processing. Plantphysiologically important factor for attaining high yield of the main-season paddy would be how to increase the photosynthetic efficiency of the rice plant.

As is explained in para. (ii), (3), 4.2.4. of Chapter 4, it has been envisaged that threee representative varieties of paddy would be introduced in the Project. The improved local variety such as Pin Gaw 56 and E Khas Puang would be planted in the low-lying paddy field below EL +1.8 m being subject to the inundation that would occur under the heavy rains with the 5-yr return period in the Project. This variety would survive under the submergence and give a useful yield after regrowth. Two high-yielding varies would be introduced to the paddy field higher than EL +1.8 m. RD 13 specifically for the Southern region would be main, however, RD 7 would be supplementary covering 25 percent due to its excellent cooking quality and non-photosensitive type in accordance with the request made by the Government. THe characteristics of improved varieties are explained in Appendix V. The following have been considered in determining the cropping schedules for these varieties.

1) Since the RD13 is a photo-sensitive variety, the beginning of harvesting period is more or less fixed at the end of February in the Southern Thailand. In order that the growing period be optimal the transplanting period should be from the early September to the end of October. Transplanting which is undertaken earlier or later than this period would inevitably result in less than the optimal, i.e., too long or too short a growing period, respectively.

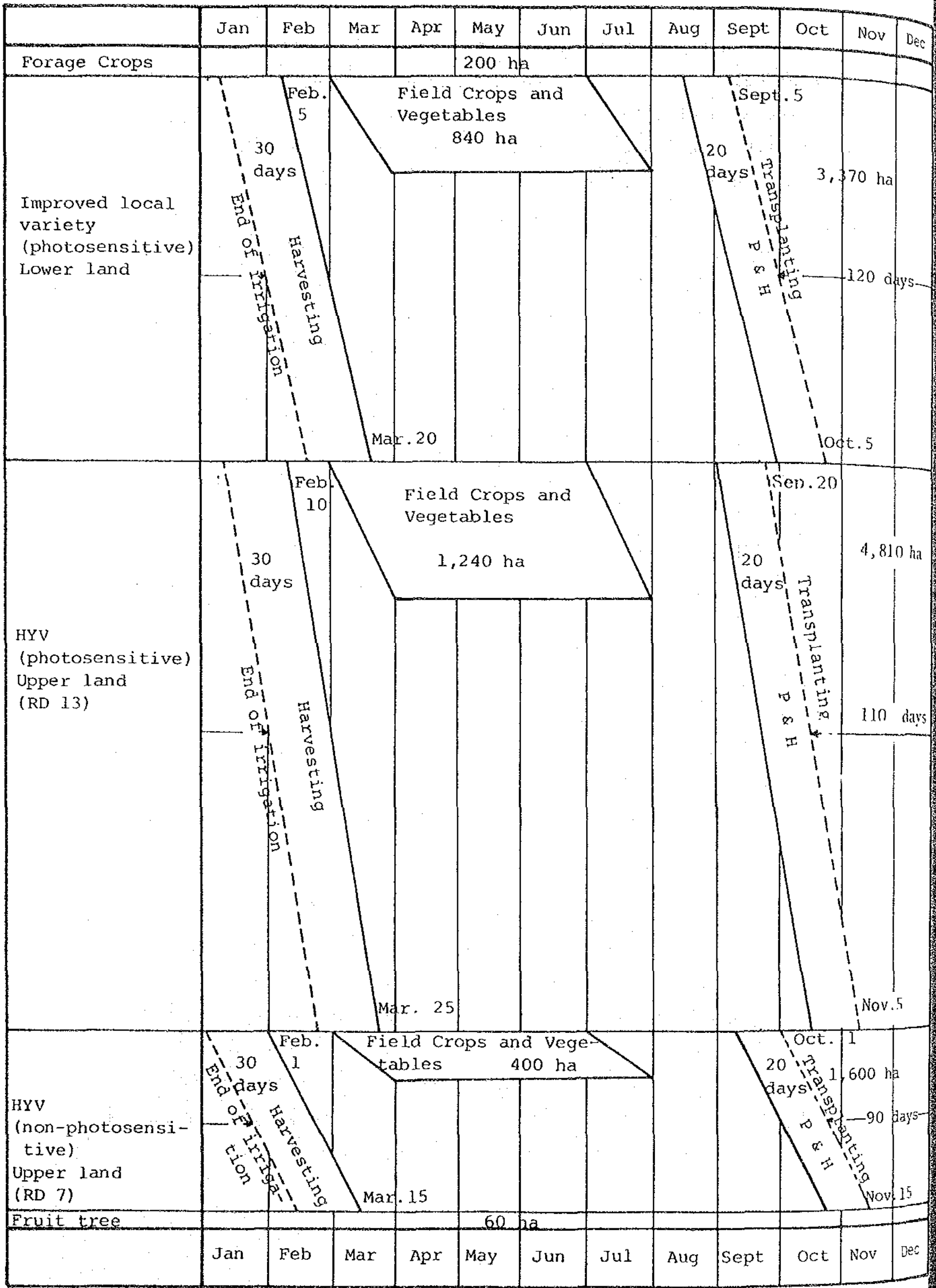
2) In order to relax the peak labor requirement in the February to March period, the transplanting and harvesting of RD7 can be started half a month or so earlier because it is a non-photosensitive variety.

3) Slight modification in the cropping pattern of improved local variety would also be possible as far as the growing period is a little longer than five months and transplanting period should not be delayed to the extent it might be affected by the flooding.

As seen in Figure 4-33, ratio of the off season field crops and vegetables cultivation acreage to paddy area would be set at 25 percent both in the area of below EL +1.8 m and in the area of EL +1.8-13 m. This has been worked out in view of the availability of farm labor forces particularly women and children of the smallholding farmers in the Project area. The cropped area to be managed by such workers per household would be 2 to 3 rai as is seen in Amphoe Waeng where such crops are largely grown on newly planted rubber land by landless rubber tappers. When an average number of the farm households in one Muban is about 120 and a participating rate of the households is 80 percent, a manageable size of the field crops and vegetables cultivation in each Muban would be 32 to 48 ha in total. This figure is compared with an average size of the paddy field in each Muban (about 155 ha), resulting in 21 to 30 percent of the off-season crops against 100 percent of the paddy cultivation during the main season. Reasons for setting the proposed cropping intensity at 125 percent are detailed in V-2 of Appendix V. When the off-season upland crop cultivation is not properly regulated, such crops would be distributed to rather scattered land and it would become difficult to distribute irrigation water because of large conveyance loss. It would be ideal to achieve a collective cultivation of such crops on the basis of a Muban cooperative service unit taking into account the special land-lease arrangements within such Muban which could lead towards a possible promotion of the better cooperative movement and a unique creation of the mutual aid system in the lowest level of the administrative system.

It is envisaged that the newly irrigated off-season field crops and vegetables of 2,480 ha would be tentatively composed of 25 percent of sweet corn, 25 percent of groundnut, 25 percent of mungbeans and 25 percent of vegetables taking into account the availability of farming labor and the possible marketing of such products to the neighboring Malaysia and Hadyai. Vegetables have been also classified into two, viz. tomato and chilli as typical ones for the planning purpose in the proposed agricultural development of the Project.

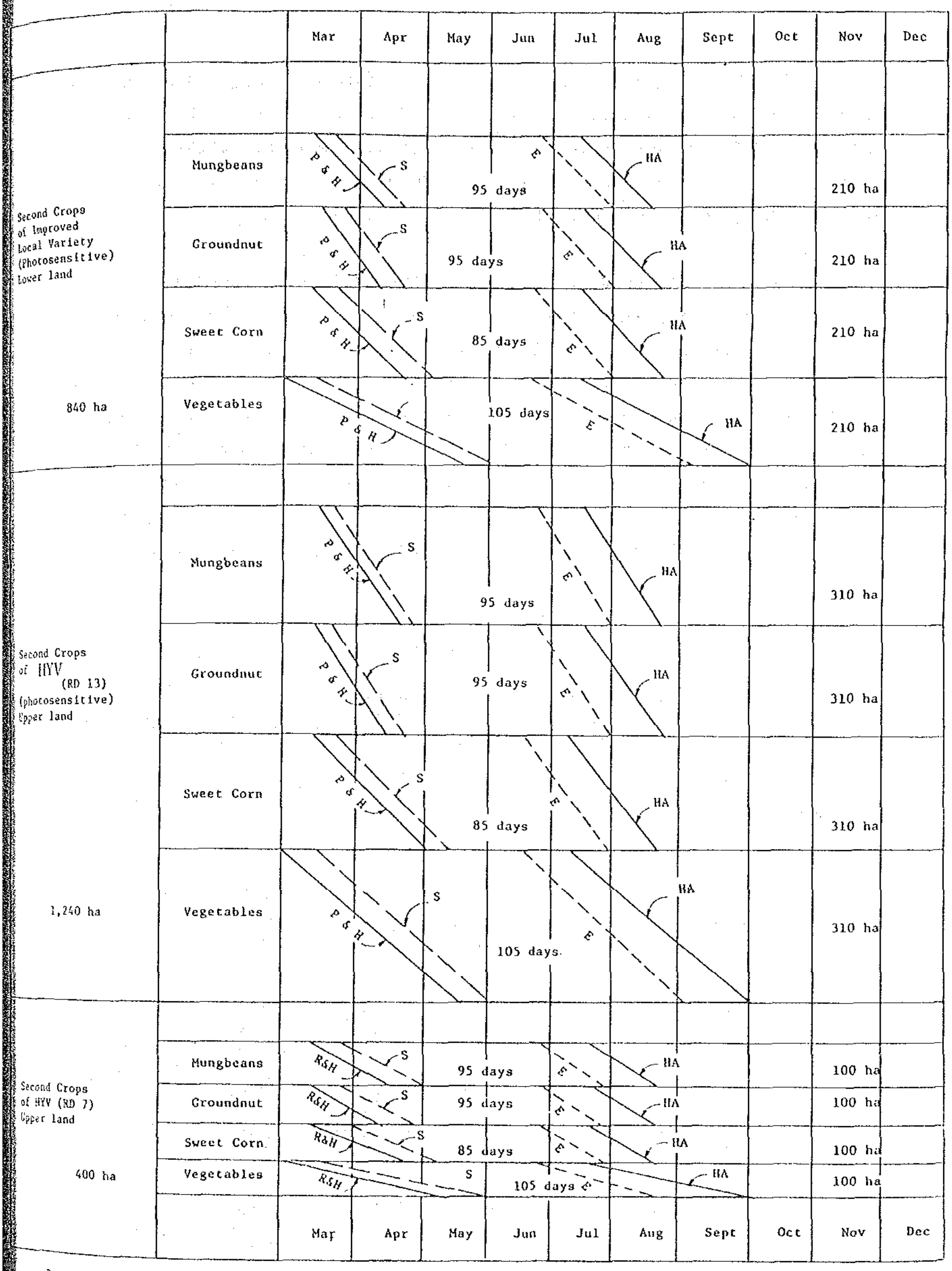
Figure 4-33 CROPPING PATTERN WITH THE PROJECT



Remarks :

1. P ---- Plowing; H ----- Harrowing
2. Detalils of upland crops are illustrated separately.

Figure 4-34 CROPPING PATTERN WITH THE PROJECT
(For Field Crops and Vegetables)



Remarks:

1. P --- Plowing; H --- Harrowing; E --- End of irrigation;
HA -- Harvesting

2. Cropping pattern for paddy cultivation is illustrated separately.

In addition, the perennial green mowed forage crops such as Torpdo and/or Para Grass have been allocated to 2 percent of the total paddy field or 200 ha under irrigation taking into account an average distribution of 3 ha per each of about 80 percent of the Muban concerned on the basis of Muban cooperative operations.

It is also intended that the promising fruit such as Long Kong which would not be directly irrigated could be introduced on the basis of Muban cooperative cultivation with an average area of one ha per each of about 80 percent of the Mubans concerned. This fruit planted area of 60 ha in total would be converted from the present communal copse-wood land where a higher groundwater table would be kept in the vicinity of the paddy fields which are irrigated during the main-and off-seasons.

Table 4-11 shows the proposed cropping acreage by crop in the Project area.

Table 4-11. Proposed Cropping Acreage

	WUG Pumping Irrigation Scheme	RID Pumping and Gravity Irrigation Scheme			Total	%
	Stage I	Stage I	Stage II	Sub-total		
(1) Paddy Field						
Total Area	3,870	1,240	4,870	6,110	9,980	100
Main-Season paddy						
Improved Local	3,370	-	-	-	3,370	
HYV (RD 13)	364	903	3,543	4,446	4,810	
HYV (RD 7)	121	300	1,179	1,479	1,600	
Sub-total	3,855	1,203	4,722	5,925	9,780	98
Off-Season Field Crops and Vegetables						
Seet Corn	241	77	302	379	620	
Mungbean	241	77	302	379	620	
Groundnut	241	77	302	379	620	
Vegetables	242	77	301	378	620	
(Tomato)	(121)	(38)	(151)	(189)	(310)	
(Chili)	(121)	(39)	(150)	(189)	(310)	
Sub-total	965	308	1,207	1,515	2,480	25
Perennial Forage Crops						
Torpedo/Para Grass	15	37	148	185	200	2
Total	4,835	1,548	6,077	7,625	12,460	125
(2) Orchard to be converted from Muban Copse Land						
Long Kong	23	8	29	37	60	

4.4.2. Projected Crop Production

(1) Improved Farming Practices, Input Requirements and Supply

Along with the completion of the year-round irrigation system, the present farming system would be improved through the introduction of modern farming techniques. It is reasonable and practicable that such improvement be carried out step by step in the Project area. The following improved farmings would be applied as the first step:

a) Introduction of high-yielding varieties of crops, especially paddy, suited for the Project area.

b) Application of fertilizers and such organic manures as compost and green manure.

c) Application of pesticides.

d) Utilization of improved plough for deep ploughing to promote the growth of plant root.

e) Utilization of such small-scale farm machines which can be operated and repaired easily by farmers as power thresher, hand-operating sprayer and duster.

f) Timely sowing and transplanting to meet the given natural conditions.

The projected production would only be realized when the extension services are positively carried out and the necessary inputs are always available to farmers.

a) Seed

Improved seeds are a precondition for achieving high yields of paddy , and the timely arrangements would be made for its multiplication in and around the Project area besides Patthalung. These seeds to be newly multiplied would be produced and distributed principally through the agricultural extension systems. It is noted that seeds of vegetables, especially hybrid seeds could not be multiplied on Changwat level for the time being and would be arranged at national level.

For the paddy cultivation, 35 kg per ha of improved local variety seeds would be needed mainly due to the non-superior quality and as for HTV seeds 40 kg per ha.

As for seeds of rice tolerant to acidic water and soil, since half a decade, necessary studies have been carried out in DOA, Bankhen as well as rice experiment station, Patthalyng. According to the information obtained from the above, presently the experiment is being continuously conducted, but the final result is not obtainable at this moment.

b) Fertilizers

Application of fertilizers would be in the form of high-quality fertilizer with a subsequent top dressing of Urea. The recommended rates for achieving respective paddy yields of three kinds of varieties are as follows:

Improved local variety (photosensitive):

Target yield: 2.8 ton/ha

Required amount of fertilizers:

60 kg/ha of Urea
60 kg/ha of Superphosphate
30 kg/ha of Potassium Chloride

HYV (photosensitive):

Target yield: 3.4 ton/ha

Required amount of fertilizers:

60 kg/ha of Urea

60 kg/ha of Superphosphate

30 kg/ha of Potassium Chloride

HYV (non-photosensitive):

Target yield: 3.7 ton/ha

Required amount of fertilizer:

70 kg/ha of Urea

70 kg/ha of Superphosphate

40 kg/ha of Potassium Chloride

Therefore, seasonal fertilizer requirements in the Project area would be worked out at 603 ton of Urea, 603 ton of Superphosphate and 309 ton of Potassium Chloride.

On the other hand, the recommended rate for achieving respective yields of field crops, vegetables, forage crops and fruit are as follows:

Mungbeans:

Target yield: 1.2 ton/ha

Required amount of fertilizer:

180 kg/ha of compound (12-24-12)

Groundnut:

Target yield: 1.8 ton/ha

Required amount of fertilizer:

160 kg/ha of compound (12-24-12)

Sweet corn:

Target yield: 3.0 ton/ha

Required amount of fertilizer:

150 kg/ha of compound (16-20-0)

Vegetables:

Target yield:15 ton/ha (as fresh tomatoes)

Required amount of fertilizer:

250 kg/ha of compound (15-15-15)

Forage crops:

Target yield: 40 ton/ha (fresh)
5 ton/ha (dry)

Required amount of fertilizer:

40 kg/ha of Urea

25 kg/ha of Superphosphate

Tree fruit:

Target yield: 4 ton/ha (as Long Kong)

Required amount of fertilizer:

15 kg/ha of compound (15-15-15)

(2) Production Potential

Recently, the Project area is confronted with the problems of agricultural economics in transition. Agricultural production, on the whole, is characterized by the production in efficiency which manifested in terms of low yields and a low adoption of modern production techniques although the production is being improved to some extent.

In the Project area, the agricultural sector is composed of about 8,680 independent farm families. The cropping system currently practised has been adopted and adapted to the local circumstances over years and formed the ways human beings organize the factors of production in order to produce the agricultural commodities. Judged from the field survey, it is considered that potential for agricultural development is rather high, especially effect to be derived from drainage improvement.

Implementation of the Project would lead to a more intensive cropping pattern and higher yields. Under the Project, the cropping intensity for existing paddy field would increase from about 70 percent at present to 125 percent. Without the Project, there would not be any significant change in cropping intensity, since the opportunities for private irrigation are quite limited. The introduction of dry season field crops and vegetables on a large scale would require important changes in cultivation techniques, such as the increased use of preemergence herbicides to reduce hand weeding requirements, the expanded use of fertilizers, and better insect control.

In the projected paddy cultivation area amounting to 9,780 ha, local improved, improved and high-yielding paddy varieties would be introduced in the wet season, so that the unit yield would be improved at a level from 2.8 to 3.7 ton per ha , and the production would become stable after completion of the Project.

Estimated yields at full development under the Project are based on current yields being achieved by few farmers in the Project area who have access to irrigation and on results obtained from the agricultural experiment stations concerned at Pattahlung and Hadyai (Refer to V-2 of Appendix V). The projected yields also take account of the heavy extension effort to be provided as part of the Project. As a result of the emphasis on extension work, it is expected that full production would be reached in five years after the development of on-farm work.

The rubber planted in the flood-prone area is currently water-logged for part of the year with consequent reduction in yields. Under the Project, drainage development is planned in this flood-prone area where many rubber trees are partly grown and its productivity is rather low, so that the rubber production is expected to increase. According to the estimate, the rubber yield over the flood-prone area would be reached at the level of 960 kg per ha on an averate in the case of the With-Project.

Table 4-12 shows the expected target yield and total crop production by crop in the Project area.

Table 4-12. Agricultural Production without and with the Project

(Unit: ha)

	Planted Area		Yield		Production		
	Without	With	Without	With	Without	With	Increase
	(ha)		(ton/ha)		(ton)		
Main Season Paddy							
Irrigation and Drainage Improvement							
	7,018	9,780			9,766	31,710	21,944
(Local Improved)	(2,366)	(3,370)	(1.3)	(2.8)	(3,076)	(9,436)	6,360
(HYV-RD 13)	(3,489)	(4,810)	(1.4)	(3.4)	(5,018)	(16,354)	11,336
(HYV-RD 7)	(1,163)	(1,600)	(1.4)	(3.7)	(1,672)	(5,920)	4,248
Drainage Improvement Only							
	354	354	1.3	1.7	460	602	142
Total	7,372	10,134			10,226	32,312	22,086
Rubber (Drainage Improvement)							
	6,250	6,250	0.71	0.96	4,438	6,000	1,562
Off-Season Field Crops and Vegetables (Irrigation)							
Sweet Corn	-	620	-	3.0	-	1,860	1,860
Mungbean	-	620	-	1.2	-	744	744
Groundnut	-	620	-	1.8	-	1,116	1,116
Vegetables	-	620					
(Tomato)	(-)	(310)	(-)	(15.0)	(-)	(4,650)	(4,650)
(Chilli)	(-)	(310)	(-)	(12.0)	(-)	(3,720)	(3,720)
Total		2,480					
Perennial Forage Crop (Irrigation)							
Torpedo/Para Grass	-	200	-	40.0	-	8,000	8,000
Tree Fruit							
Long Kong	-	60	-	4.0	-	240	240

(3) Demand and Supply of Rice

For the estimation of marketable surplus of rice, the balance of demand and supply of rice in the Study area is examined on the basis of following assumption:

a) Waste and seed requirements are taken as 18 percent of total production of paddy.

b) Milling recovery rate from paddy to rice is 1:0.66.

c) Annual per capita consumption of rice is 160 kg taking into consideration the FAO estimate.

Paddy production	34,219 ton
(Without the Project	12,133 ton)
--- refer to para. 3.4.4 of Chapter 3.	
(Increase with the Project	22,086 ton)
--- refer to Table 4-12.	
Seed and Waste	6,159 ton
Rice supply	18,520 ton (A)
Projected population	76,260 at full development
Rice consumption	12,202 ton (B)
Surplus of rice (A-B)	6,318 ton

In the Study area, surplus of rice is expected after completion of the Project.

4.4.3. Agricultural Support Services

(1) Demonstration Farms

(a) Objective

The demonstration farms proposed in the Project is to demonstrate advanced farming management as well as improved irrigation farming practices.

(b) Function

Irrigation farming techniques as little known and scarcely practised would be promptly introduced in the Project area through proper implementation of the demonstration farms. The main objective is to disseminate to farmers new irrigation farming techniques through their own cultivation.

*Farmers accustomed to the traditional farming are not always utilizing improved crop varieties, and are not fully applying fertilizer and agro-chemicals in the most effective way. Practically, they need to be shown what kind of improved varieties are most adequate for the Project conditions, and what is the proper use of fertilizer and agro-chemicals, and their effects on the farms.

*Farmers in the Project area have been rather careless about water control and management on their field. Side by side with infrastructural implementation, particularly in irrigation and drainage facilities, they need to learn how to save irrigation water through intensive water control and how to use it more effectively through proper water management.

*Upland crops in the Project area were produced to lesser extent primarily for the cultivators' own domestic consumption, excluding some industrial crops like tobacco. Continuous irrigated cultivation of the marketable crops as offered in the Project would cause conspicuous problems. Crop diversification and rotation practices are important and valuable for farm economy as well as soil and water conservation. Desirable crop rotation would be demonstrated to them.

(c) Selection of demonstration farm sites

As soon as the general framework and arrangement for implementation and development of the Project is finalized, a definite selection of the demonstration farm sites would be made. The following criteria are important in this selection:

i. Demonstration farm sites must be placed in respective Amphoe taking into account the easy reach of all Project farmers.

ii. Irrigation water must be available throughout a year.

iii. Already available services including agricultural extension service must be fully integrated.

iv. The site chosen must be also suitable for building the related facilities.

v. The site must be chosen in such way that the farms would be useful for the technique dissemination.

vi. The final location should be made only after a detailed topographic and soil survey.

(d) Location and size

It is proposed that three demonstration farms would be located in Amphoe of Muang Narathiwat, Rangae and Tak Bai, respectively. The place and size so far examined and discussed in this Study are as below:

No. 1 Ban Ku Ra So Demonstration Farm (13.8 ha)
Tambol Lamphu, Amphoe Muang Narathiwat

No. 2 Ban To Lang Demonstration Farm (23.5 ha)
Tambol Tanyongmilo, Amphoe Rangae

No. 3 Ban Cha Ro Demonstration Farm (26.1 ha)
Tambol Phraiwan, Amphoe Tak Bai

(e) Facilities, supplies and materials

The proposed facilities consist of the following:

Facilities:

Irrigation and drainage on-farm work and water source facilities

Supplies and materials:

Fertilizer, agro-chemicals and seed

(f) Operational layout

The management of an irrigation and drainage project can be vested with many responsibilities for promoting the technical and economic prosperity of all the farms. They are demonstration and extension work providing for the farmers' credit and marketing facilities. Demonstration is essential for determining different agronomic features important for irrigated farming. Factual information would be made readily available to the farmers who are prepared to apply them without delay. This involves efficient extension agents with several highly trained staff of technicians whose task is not only to bridge the gap between the trial services and the farmers but also to ensure that the farming operations are performed in time and up to standard.

In operating the demonstration farms, especially the following matters would be considered:

*to collect technical information and diffuse them to the farmers.

*to demonstrate intensive irrigated farming.

*to demonstrate rationalized water management and minimize the irrigation cost.

*to promote and organize farmers' group for strengthening of the demonstration farms' activities.

*to do best to receive farm inputs such as fertilizer and agro-chemicals at lowest cost.

On the basis of the above, prior to the commencement of constructing the demonstration farms, a necessary organization and procedure responsible for the operation would be established. Reference is made to para.7.2 of Chapter 7 where a Special Task Force Unit is proposed to organize in the Project. The agricultural extension staff in the Special Task Force Unit would pay extra attention to the supply of all inputs to the demonstration farm areas including seeds, fertilizers and pesticides as well as the electricity charge to operate the temporary deep wells. With respect to the supply of inputs such as fertilizers and pesticides for the demonstration needs, it is suggested that the distribution of such commodities to be procured under the Japanese Grant Aid for Increasing Food Production (so called "KR II Aid") would take advantage of lower price for the Project in Changwat Narathiwat. The fertilizers are currently distributed by MOF, while the pesticides by DOAE. The Special Task Force Unit would supply all the above mentioned inputs at his own risk, and such cost would be reimbursed by the relevant farmers after their harvesting.

(2) Extension and Research

Extension

When the Project area is to make a better contribution to the economic development of Changwat Narathiwat, the agricultural extension would be greatly expanded. Within the limitations in which they work, the Narathiwat farmers achieve fair results from their labors. To make farmers understand new knowledge and techniques, each extension agent would employ effective extension and guidance methods, and for this purpose, he would accumulate experience. When the extension agent dispatched to the Project comes to know the situation of this area, he would be inevitably attracted what seem to be the farmers' problems, and he would think of approaching farmers to ask them about their interest. He would also try to know the level of knowledge and techniques required for solving such problems. To attain the highest possible effect from his activities, the extension agent would most probably have to "contact individuals separately for guidance activities".

The basic extension is a systematic training program to be conducted by the extension agents, especially the Muban level extension agents to be combined with frequent visits by them to farmers' fields. The system would be organized to give the intensive training in those specific agricultural practices and recommendations relating directly to farm operations during a given week or fortnight. The training and visit system is the most important extension method to be used by the reorganized extension services.

The number of farm families that one extension agent covers varies considerably from place to place depending, among other things, on the density of population, the road conditions, the intensity and standard of cropping, and the types and diversity of crops grown. In the area where (1) the population density is high with many small farmers living close together and (2) the cropping intensity is fairly low and only a few main crops dominate agriculture, a ratio of one extension agent for 800 to 1,000 farm families would generally be adequate. When the population is more widely dispersed, or agriculture is more intensive as in the demonstration farm and its vicinity, a ratio of one extension agent to 500 farm families would be more effective.

To ensure that the Project has sufficient manpower to fulfill its accelerated agricultural extension responsibilities during the initial period of its implementation, DOAE would need to appoint about 17 additional extension workers (Kaset Tambol) who would be familiar with the irrigated agriculture as envisaged in the Project, on the basis of the programme which would provide one extension worker for about 500 farm families. In the present absence of such extension workers in the Project area, some of the qualified staff would be recruited from other regions in the initial stage; however, it would be imperative to train the staff who can speak Jawi and take good communication with the largely Muslim farmers in the Project. The Special Task Force Unit would be responsible for on-the-job training or guiding of such required extension workers by applying the demonstration activities at three sites and other opportunities in the regional training center or another suitable training facility.

Extension advice would cover the entire production cycle including (1) selecting appropriate seed varieties and seed sources, (2) obtaining institutional credit at reasonable interest rates; (3) maintaining a correct, weed-free plant stand; (4) selecting appropriate fertilizers and pesticides and applying them correctly; (5) preliminary processing of outputs to a reasonable standard quality to ensure marketability. The extension workers would be trained to take a whole farm approach to extension; hence, their recommendations would be finely turned to suit local circumstances. In addition, the extension staff would have a proper training or guidance in the prepared agricultural development planning in the Project under the positive coordination of the Special Task Force Unit.

Extension worker, together with the muban authorities and the WUG's key staff, would select about 10 contact farmers from among the farmers who are respected by their neighbours, who are receptive to improvements in agricultural techniques, but who are not always rich farmers with extensive holdings. The extension worker would work mainly with contact farmers during his scheduled weekly or biweekly visits, but all farmers would be invited to be present. During his visit, the extension worker would demonstrate to them the practices which are followed before the next scheduled visit and assist the contact farmer in laying out a demonstration plot. After each visit, each contact farmer would be responsible for imparting the recommendations to his neighbours or relatives with whom he has contact on daily basis and often works cooperatively.

Every fortnight, the extension workers and Amphoe extension officers would attend a one-day technical instruction session at an Amphoe Extension Center or Office of the Special Task Force Unit which would be conducted by the subject matter specialists and other experts when required and available. To foster close cooperation and become familiar with other agencies involved in farming activities in irrigated areas, staff of the Special Task Force Unit and other agencies such as LDD, DLD and BAAC would be invited to participate in the above mentioned sessions. The session would mainly cover the practical information to be imparted to the farmers in the next two weeks, more particularly, beginning with a review of the last fortnight's experiences and a lecture, followed by field work when participants would go through all steps of the recommended techniques and finally group discussions. The extension workers would also attend seasonal instruction sessions to plan approaches for improving the subsequent cropping cycle.

Each of the extension workers would be given the opportunity to obtain a motorcycle on a hire-purchase agreement to ensure the mobility required to meet the schedule of field visits and on-the-job training at the demonstration farms. DOAE and the Special Task Force Unit would be provided with a total of 39 vehicles including 2 station wagons, 29 motorcycles, 3 pick-up trucks and 5 flat bed trucks which would be used to transport personnel to training sessions and field days as well as training personnel and materials, and demonstration equipment, inputs and materials.

On completion of the development phase of the subprojects, the regular extension service would revert to the established DOAE boundaries. As is scheduled in Figure 7-3 of Chapter 7, the accelerated agricultural extension services would be terminated in the Project year

16 with the completion of five year-irrigation development for 18 tertiary units or 357 ha for which the on-farm work would be constructed in the Project year 11. After this, more intensive services would also be funded from the regular DOAE budget. Continued close cooperation between DOAE and the Project implementing agencies especially RID would thus be maintained, so that adjustments in the operation mode or in the staffing ratios could be arranged when necessary.

Research

DOA is responsible for research on rice. According to DOA, Bangkok, the rice research has been regionalized with a regional station at Patthalung and its substation at Pattani. DLD is responsible for soil survey, land classification, formulating land development proposals and research on problem soils. Currently, DLD is active in carrying out more detailed soil surveys in the Study area, especially in potential acid sulphate and organic soil areas, and is conducting soil management study. Furthermore, the educational and development center of Pikul Thong located in Amphoe Muang Narathiwat is responsible for various researches on soil and crop, especially those in swamp areas.

Judged from the present research and survey work, the following research and survey work are considered necessary for paddy production in the Project:

a) Intensification of rice selection and breeding to develop varieties better adapted to the low-lying area being subject to inundation and tolerable to acid soils taking into account the insect and disease control.

b) Fertilizer requirement by soil type and optimum rates of N and P application to maximize farm profits.

c) The extent, severity and nature of acidification.

Input supply

Availability of high quality seeds or planting materials is rather low in the Project area, but such a status is expected to be gradually improved through the joint efforts of DOAE and MOF. Of these departments, MOF provides a fund to purchase and distribute seed with the assistance of extension workers. Presently, fertilizers and agrochemicals are mainly purchased from local traders, but in the future, it is expected that agricultural cooperatives and farmers' associations, through MOF, become increasingly important as suppliers of inputs.

Credit services

The major institutional source, BAAC supplies at present only a small percentage of available credit, but its role would increase under the Project. The BAAC's lending criteria would be reasonable and it is in a financially sound position. Assuming 40 percent of all cash inputs to be financed on credit, the credit needs of the farmers are expected to rise to ฿ 16 million at full development. To ensure that these needs would be adequately met, BAAC would increase its trained staff at Narathiwat branch office, and make available such funds both short-term and long-term as needed to meet the credit requirement of the farmers. The issuance of land titles would remove another problem of the farmers' eligibility for the BAAC credit.

(3) Storage, Processing and Marketing

Storage

The large increase in the main-season paddy production would present a storage problem. To put the farmers in a more competitive position in the marketing system, it is proposed that the bulk of increased storage would be provided at the farm level. A program would be initiated to upgrade the existing farm storage and provide for construction of new storage which is wood-made. Some further study of storage needs at full development would be carried out for the prospected field crops, vegetables and fruits by the Project management.

Processing

In developing crop processing, first of all, four essential factors of the production would be considered including i) raw material, ii) labor, iii) market, and iv) capital. Judged from the present and future situations of the Project, the processing in this area would not need to be developed solely in view of getting more cash income from outside markets, and it would be encouraged to satisfy the self-generating demands in the locality for its general productivity increase. The above-said processing would be developed in a way complementary to the success of a community development scheme which is closely bound to agricultural economy of the Project area. Also it would be operated through participation of all the farmers in the area on the principle of equitable distribution of its fruits among the farmers concerned.

Processing to be developed in the Project area, therefore, would be conveniently grouped into two :

i) those which would be operated throughout a year requiring no particular factories nor machinery; and

ii) those primarily concerned with the processing of locally available farm produce from season to season - simple plant and equipment of the cottage industry type and labor organized to a certain degree would be required for their operation.

Marketing

As mentioned repeatedly, the present crop production is low due to low production efficiency. Land utilization for cash crop cultivation is rather on marginal areas around houses and on few commercial plantation. Thus, marketing system is grossly wanting.

Aside from the paddy, rubber and forage crops, the proposed irrigated field crops and vegetables to be cultivated in the Muban cooperative manner during the dry season would consist of mungbeans, groundnuts, sweet corn and vegetables taking into account the possible marketing of such cash crops to the neighbouring Malysia through existing outlet at Sg. Kolok and on-going development of the Taba/Tak Bai foreshore with the ferry terminal as explained in para.3.5.2 of Chapter 3 and also to Hadyai in addition to the home consumption in the Project area.

It is considered that the key problem that would frustrate the proposed field crop and vegetable cultivation scheme during the dry season would not be markets but marketing. The following three principal conditions have been identified so far by a number of the studies:

a) Awareness of the markets:
   Farmers and agricultural extension workers are not aware of the demand of local, regional or national market outlets.

b) Awareness of the production potential:
   Middlemen and processors are not aware of the bumper production potentials in the irrigated area.

c) Quality control:
   Commodities produced by farmers in the Government operated irrigation project are of low quality being unacceptable to all but local markets.

Farmers generally lack the knowledge of quality standards; therefore, since the produce quality is low, the prices offered are also low. Farmers typically want to sell at the seasonal production peaks, resulting in lower prices. Farmers particularly have little knowledge of the post-harvesting technology which can clean, grade, dry and store the harvested crops to fetch better market prices. Farmers are not properly organized to offer a consistent, adequate volume of raw materials to the processors and middlemen who depend upon such supplies. Two principal institutions of the Government support for marketing activities such as the Public Warehouse Organization (PWO) and the Marketing Organization for Farmers (MOF) would appear to be ineffective in dealing with these problems. In 1981, the Government established a joint Public-Private Sector Consultative Committee to assist the private sector in solving the rural marketing problems as pointed out above, and it has given little impact at the field level to date.

It is proposed that a programme to create better links between the cash crop production to be anticipated in the Project and the existing marketing system would be launched under the leadership of the Project Changwat Development Committee to be supported by the Project Central Committee to ensure that the field crop and vegetable cultivation during the dry season as envisaged in the Project could be promoted and continued. The programme would be composed of three factors:

a) Research to identify traders and potential investors, marketing channels and price patterns in local, regional and export markets.

b) Marketing extension to develop, among the agricultural extension workers and the farmers, an awareness of markets, marketing techniques and advantages of practicing mixed farmers with marketable cultivation period which would be done primarily through the training.

c) Market development activities to meet the needs of private investors and encourage their participation in alleviating the marketing problems of such cash field crops as proposed in the Project.

(4) Rubber Planting Scheme

Rubber replanting in Thailand has been in progress for more than 15 years, and it is assumed that the majority of rubber growers see the advantages of successful replanting with high yielding varieties. According to ORRAF, Bangkok, 0.48 million ha or 34 percent of the total rubber growing area in Thailand has been replanted since 1961.

If the current rate of replanting (21,600 ha per year) continues, it would take at least 16 years to complete replanting of 35 percent of old mature unselected holdings. By that time the remaining 65 percent of young mature holdings might have reached the replanting age. It would thus require another 30 years to complete the replanting of this last category.

A project for acceleration of rubber replanting proposed by ORRAF aims at increasing the rate of replanting from 21,600 ha per year. This rate would enable the project to maintain the economic life of rubber tree to a 30-yr replanting cycle. This optimum rate of replanting is undoubtedly desirable for a number of reasons, but unless the better responses from smallholders to the new project are apparent, it would not be fully successful. Although rubber replanting in Thailand has so far been successful, the rate of replanting is low at about 1.5 percent per year compared with those in other countries.

According to the field survey, the rubber planted area in the Study area amounts to 8,320 ha in total:

Table 4-13. Rubber Acreage by Amphoe in the Study Area (ha)

Item	Muang Narathiwat	Rangae	Tak Bai	Yingo	Total
Total	3,010	4,590	320	400	8,320
Young	695	1,372	108	52	2,227
Young in tapping	1,277	2,346	175	330	4,128
Old	1,038	872	37	18	1,965

Finally, it is noted that the rubber smallholders have two main constraints towards the existing rubber replanting scheme:

a) Physical constraints

The main physical constraints to replanting would be terrain and communication. In the Project area, more than half of rubber holdings are in high-lying areas, and some are often far way from the houses where owners and tappers live. Such areas are difficult to work on and, therefore, extra costs are involved in clearing and terracing the sloped land. In many areas, communication is only possible by foot, bicycles or motorcycles and this is time consuming. Transportation of heavy loads such as fertilizers is almost impossible and costly. The ORRAF grant, however, does not take into account all the extra costs necessary to complete the initial stage of replanting.

b) Economic constraints

Economic constraints to replanting would be classified into five, i) availability of land, ii) labor, iii) capital, iv) profitability, and v) entrepreneurial skill. For example, a smallholder who participates in the replanting scheme would decide upon the alternative sources of income during the immature period of replanting. A large holding on the other hand, would be able to organize its replanting schedule, so that sufficient cash is always forthcoming from other mature rubber in tapping.

In line with the drainage improvement for current rubber ara under the Project, an accelerated scheme of the replanting for the rubbers that are unselected seedling materials of low yield potential and over-aged has been examined. The discussion with ORRAF, Bangkok, has indicated that such need as mentioned above would be absorbed with the operational procedures of the ORRAF national rubber replanting project.

CHAPTER 5 PROJECT FACILITIES

5.1 Tidal Regulators

5.1.1 Site Topography, Geology and Soil Properties

(1) Upper Tidal Regulator (UTR)

1) Topography

UTR site is located approximately 6 km upstream of the Narathiwat estuary in Mae Nam Bang Nara. The regulator site indicates an elevation of around +1 m and is almost flat. Small streams are formed here and there and the site is swampy in some parts. The river width at the Bang Nara closure site is approximately 200 m. Granite is seen outcropping on the river bottom near the Sapi Yo closure site. Topographic map of the UTR site is shown in Figure IX-1-1 of Appendix IX.

2) Geology

Profiles

Geological profiles are shown in Table 5-1. The geological cross-sections of the proposed sites for regulator body, closure dam, etc. are shown in Figure IX-1-3 to IX-1-5 of Appendix IX.

Soil Properties

Soil properties of each layer are explained in Table 5-2, in which the following conditions have been given:

Bulk density --- empirically obtained from the soil classification and N-value.

Cohesion --- obtained from N-value according to the Terzagi's formula ($C=N/16$).

Angle of internal friction --- obtained from N-value according to the Peck's formula ($\phi = 0.3N + 27$).

Compression index --- obtained from the liquid limit according to the Terzagi's formula ($Cc = 0.009 (WL - 10)$).

Nature void ratio --- obtained by the equation of $e = Cc/0.46 + 0.4$.

Coefficient of permeability --- obtained from the distribution of 20 percent of particle grain size by the Creager's relationship.

(2) Lower Tidal Regulator (LTR)

1) Topography

LTR site at Tak Bai is located approximately 7 km upstream of the Mae Nam Kolok connection, and approximately 10 km upstream from the estuary of Mae Nam Kolok. The elevation of the regulator site which is currently being used as paddy fields is around +0.75 m. The neighborhood of the closure site on the right bank is lower in elevation than the regulator site and becomes inundated at high tide. The river width is about 60 m. Topographic map of the LTR site is shown in Figure IX-1-10 of Appendix IX.

2) Geology

Profiles

Geological profiles of the regulator site and the closure site are different as shown in Tables 5-3 to 5-4. The geological cross-sections of the proposed sites for regulator body, closure, dam, etc. are shown in Figure IX-1-12 to IX-1-13 of Appendix IX.

Soil Properties

The soil properties of each layer are presented in Table 5-5. Bulk density, nature void ratio, cohesion, angle of internal friction, compression index, and coefficient of permeability are estimated by the same methods as applied to UTR.

(3) Rock and Earth Materials

On the basis of the general geological conditions in and around the Study area as described in Appendix I, the embankment materials are distributed as shown in Figure IX-1-19 of Appendix IX, and the distribution of existing borrow areas is also indicated on the same figure. The fresh zone of granite is used as rock material and the weathered zone as soil material.

Colluvium and residual soil mainly consist of sandy clay and are used as embankment material for the Pileng project, but they are not considered good materials being lean of sandy contents. Laterite is distributed with layer thickness of 2 m near Sg. Kolok and is extracted for the Mu No project. This laterite is considered to be good material with satisfactory grain size distribution. Laterite is also distributed at various places around the Study area, but the layer thickness is thin mostly being less than 1 m.

Beach-sand is mainly seen along the beach ridge in the coastal zone and consists of fine to coarse sand. This layer is extracted here and there on a small scale. River sand is distributed in Mae Nam Ya Kang and Mae Nam Kolok, being extracted on a small scale by small pump dredgers.

Table 5-1 Geological Profiles (UTR)

Mark	Layer	Soil	E L to base of layer (m)	Remark
	Asu	sand, silty sand locally sandy silt	-5.9~-8.15	
	Acu	silty clay clayey sand	-8.0~-11.29 (locally -17.82)	
	Asl	sand silty sand locally sandy silt	-19.05 >	
	Acl	silty clay	-22.21 >	Very locally
	Gr	granite	—	Closure site

Table 5-2 Soil Properties (UTR)

LAYER	Asu	Acu	Asl
SOIL	Sand. Silty Sand locally Sandy Silt	Silty Clay Clayey Sand	Sand. Silty Sand locally Sandy Silt
N- VALUE	1 ~ 12	0 ~ 7	10 ~ 50
20% OF PARTICLE GRAIN SIZE (mm)	0.07 ~ 0.16	-	0.09 ~ 0.54
LIQUID LIMIT WL(%)	-	28 ~ 46	-
SOIL CLASSIFICATION (ASTM)	SM ~ SC SP	CL ~ ML	SP. SW. SM ~ SC
BULK DENSITY rt (g/cm^3)	1.7	1.7	1.9
NATURE VOID RATIO e_n	-	0.7 ~ 1.1	-
COHESION C (kg/cm^2)	0	0.03 ~ 0.44	0
ANGLE OF INTERNAL FRICTION ϕ (°)	27 ~ 30	0	30 ~ 42
COMPRESSION INDEX Cc	-	0.16 ~ 0.32	-
COEFFICIENT OF PERMEABILITY K (cm/s)	6.5×10^{-4} ~ 5.1×10^{-3}	-	1.4×10^{-3} ~ 9.2×10^{-2}

Table 5-3 Geological Profiles (LTR-Regulator Site)

Mark	Layer	Soil	E L to base of layer (m)
	Ac1	clay silty clay	-5.5
	Ac2	clay silty clay	-10.0 ~ -16.5
	Ac3	sandy silt	-12.0 ~ -18.5
	Ac4	clay silty clay	-19.2 ~ -26.0
	As2	sand silty sand	--

Table 5-4 Geological Profiles (LTR-Closure Site)

Mark	Layer	Soil	E L to base of layer (m)
	Acr	silty clay	-8.3
	Ac1	clay ~ silty clay	-2.0 ~ -3.2
	As1	silty sand	-6.9 ~ -12.0
	Ac3	sandy silt	-14.9 ~ -16.1
	Ac4	clay ~ silty clay	-28.8 ~ -33.2
	As1	sand	-24.9
	As2	sand ~ silty sand	—

TAble 5-5 Soil Properties (LTR)

LAYER	Ac1	As1	Ac2	Ac3	Ac4	As2
SOIL	Clay ~ Silty Clay	Silty Sand	Clay ~ Silty Clay	Sandy Silt	Clay ~ Silty Clay	Sand ~ Silty Sand
N-VALUE	0	1~9	0~1	0~7	1~8 (5~12)	7~50
20% OF PARTICLE GRAIN SIZE (mm)	-	0.05~0.09	-	-	-	0.05~0.75
LIQUID LIMIT WL (%)	51~61	-	46~49	15~24	44~50	-
SOIL CLASSIFICA -TION (AASHTO)	CH	SM~SC	CL	SM~SC ML CL	ML CL	SP SM~SC
BULK DENSITY t (g/cm^3)	1.4	1.7	1.6	1.7	1.7	1.9
NATURE VOID RATIO n	1.2~1.4	-	1.1~1.2	0.5~0.7	1.1~1.2	-
COHESION C (kg /cm^2)	0.03	0	0.03~0.06	0.03~0.44	0.06~0.50 (0.31~0.75)	0
ANGLE OF INTERNAL FRICTION ∅ (°)	0	27~30	0	0	0	29~42
COMPRESSION INDEX Cc	0.37~0.46	-	0.33~0.35	0.05~0.13	0.31~0.36	-
COEFFICIENT OF PERMEABILITY K (cm/s)	-	2.8×10^{-4} ~ 1.4×10^{-3}	-	-	-	2.8×10^{-4} ~ 1.9×10^{-1}

note: ( ) Closure

5.1.2 Preliminary Design

(1) General Concept

The most fundamental facility in the proposed Project is the tidal regulators to establish the Bang Nara water storage which are to be constructed at the UTR and LTR sites as is explained in Chapter 4. The function to be given to the tidal regulators is vested by operating the gates intercepting the intrusion of tidal flow from the ocean and controlling the impounding water level of the water storage.

During the preliminary design stage of two tidal regulators, a thorough discussion with the Government agencies concerned was made on the needs of fish ladders and navigation locks to be attached. While two tidal regulators would cut off the present migration of some fish species from their brackish spawning to the fresh growing ground that would be minor, it has been envisaged that any fish ladder would not be essential and this could be fully compensated by the artificial fish fly stocking into the Bang Nara water storage. As far as the navigation locks are concerned, the present condition of navigation along Mae Nam Bang Nara indicates that there are few fishing boats and small local vessels to convey the forest products including charcoal. It would not be acceptable to provide the navigation locks at the regulator sites for such need taking into account the rather high investment and complicated operation of navigation locks. It is expected that some forms of the current river navigation would be converted to the transportation with existing well-designed road network.

As a consequence of construction work, the regulator body is constructed in the form of dry work, and then is connected with both upstream and downstream of Mae Nam Bang Nara by the connection channel. Since the flow of Mae Nam Bang Nara is possible to be diverted through the connection channel and regulator, the old river channel is blocked up by the closure dam. The crest of regulator is served as road to facilitate local traffics and O & M of the Project after construction.

Detailed information of the site geology and soil mechanics as well as the regulator design are incorporated in Appendix IX, while 10 drawings compiling a preliminary layout of the tidal regulators at UTR and LTR are attached at the end of this Report.

(2) Type, Size and Operation of Gates

The effective gate opening width of regulators has been given at 120 m at UTR and 24 m at LTR in total under Chapter 4. Taking into account the water pressure conditions for the gates being subject to both the inside and outside pressure as well as the overflow actions, a roller type is preferably employed for the regulator gate. In addition to facilitate the operation and management of the water storage, it is designed that one of the gates at each site is of 2-leaf roller type.

One span length of the gates is determined after examining a paractical ratio of the leaf dimension as a shell-type structure, weight of leaf and its construction cost, as is explained in para. IX.1.2 of Appendix IX.

The major design dimensions of two tidal regulators as delineated are summarized below:

Openings

	UTR	LTR
Elevation of still	EL-4.0 m	EL-5.0 m
Effective opening width in total	120 m	24 m
Flood conditions		
- At 50-yr return period (Design term):		
Downstream level	EL+2.32 m	EL+2.20 m
Upstream level	EL+3.25 m	EL+1.92 m
Max. outflow through regulator	1,911 cu.m per sec	326 cu.m per sec
- do - velocity	2.20 m per sec	2.04 m per sec
- At 5-yr return period:		
Downstream level	EL+1.63 m	EL+1.44 m
Upstream level	EL+2.23 m	EL+1.47 m
Max. outflow through regulator	1,229 cu.m per sec	185 cu.m per sec
- do - velocity	1.65 m per sec	1.25 m per sec
Normal impounding water level	---------- EL+0.40 m	---------
Minimum impounding water level	---------- EL-0.20 m	---------

Gate specifications

	UTR	LTR
Type		
One-leaf roller, shell type	5 spans	-
Two-leaf roller, shell type	1 span	-
One-leaf roller, girder type	-	1 span
Two-leaf roller, shell & girder type	-	1 span
Clear span	20.0 m	12.0 m
Gate crest	EL+1.1 m	EL+1.6 m
Gate height	5.1 m	6.6 m
Operating floor	EL+12.10 m	EL+12.10 m
Seal type	------ 3-side rubber seal -----	
Hoist	------- Wire rope winch ------	
Operating speed	------- 0.3 m per min --------	
Lifting height	8.00 m	8.00 m
Total weight	660 ton	180 ton

It is proposed that an integrated operation and management of the tidal gates and the Bang Nara water storage as a whole would be introduced with the provision of a water level information transmission system by wiring among two regulators at UTR and LTR, for which a central station is located at UTR. As far as the gate operation is concerned, three kinds of the systems are taken for UTR and LTR:

- In-situ control to operate the gate at local positions.
- Remote control to operate the gate from the UTR and LTR control rooms.
- Automatic control to operate the upper leaf of two-leaf gate from the UTR and LTR control rooms with the water level indicator and automatic control unit.

In addition, in case of the PEA's power loss, emergency diesel engine generators of 56 kVA for UTR and 40 kVA for LTR with a capacity to operate two gates progressively are installed.

(3) Regulator Body

1) Pier

The tidal regulator body is made of reinforced concrete. The gate is supported by the pier, and the concrete shelter at its top is provided with hoist equipment and electric motor. The gate pier and the abutment and pier of the road bridge compose an integrated structure, and are constructed separately from the apron of the waterway.

2) Cut-off

Cut-offs are provided to prevent the destruction of the foundation ground due to the piping action of the water infiltrating in the ground. The length of the cut-off is calculated by the Lane's formula which examines the safety of the foundation soil with regard to the infiltration route length:

$$C \leqq \frac{L/3 + \Sigma \ell}{\Delta H}$$

where

C: Weighted creep ratio

(C = 8.5 for fine sand or silt)

L : Horizontal creep length

ℓ : Vertical creep length

ΔH : Differential water level between upper and lower courses

The cut-off length would be 4.0 m for both UTR and LTR, consisting of a row of steel sheet piles.

3) Apron and riprap

Concrete structure apron would be provided so as to prevent the scour of the river bed due to the flow of the flood at the upper and lower courses of the pier. The rear apron at the downstream side is calculated by the Bligh's formula:

$$\ell = 0.9\ C\ \sqrt{D}$$

where

ℓ : Rear apron length

D : Maximum differential water level between upper and lower courses

C : Value of the Bligh's coefficient
(C = 18 for fine sand or silt)

It is decided to adopt the rear apron length of 10 m at UTR and 13 m at LTR. In general, the fore apron length is approximately three times the pier width, and it is decided to adopt 8 m at UTR and 7 m at LTR. Furthermore, the riprap would be provided in succession to the upstream and downstream aprons, and its length would be 45 m at the downstream side and 20 m at the upstream for UTR, and 40 m and 20 m, respectively for LTR.

4) Foundation pile

The foundation ground of the regulator is loose sand stratum at the UTR site and soft clay stratum at the LTR, and no bearing capacity can be expected. Therefore, the regulator body and apron would be supported with pile foundation. At the UTR site, there is the sand stratum with N-value of 20 to 25 in the vicinity of EL-12 m which would be considered for good foundation and of more than 50 at around EL-17 m as deemed solid foundation, as are seen in Figure IX-1-6 of Appendix IX. As for the design bearing capacity of the pile, the ultimate capacity with no settlement is calculated by the Meyarhof's formula taking into neglect the friction bearing capacity by pile's surface, and then it is multiplied with the safety factor of 3:

$$Ru = 40N \times Ap$$

$$N = 15 + 1/2\ (N' - 15) \qquad N' > 15$$

$$Ra = Ru\ /\ 3$$

where

Ru : Ultimate bearing capacity

Ra : Allowable bearing capacity

N : Guaranteed N-value

N' : Average N-value at the pile tip

For pier pile, pile tip is at EL-17.5 m with N' of 50.

For apron pile, pile tip is at EL-11.0 m with N' of 20.

Ap : Pile tip's area (0.4 m x 0.4 m = 0.16 sq.m)

The allowable bearing capacity (Ra) of the foundation pile is calculated at 69 ton for pier and 37 ton for apron, while the pile load according to the arrangement as specified in the Drawings No.R2 and No.R3 is 64 ton per pile for pier and 26 ton per pile for apron.

At the LTR site, the foundation consists of soft silty clay layer down to EL-20 m, and the design pile length for both the pier and apron would be 18 m where the tip is at EL-24.5 m so as to support them at the sand and silty sand stratum with N-value of 40 or higher in accordance with Figure IX-1-14 of Appendix IX. The allowable bearing capacity (Ra) of the pier foundation pile at N' = 40 is calculated at 55 ton which is higher than the pile load of 50 ton. The apron pile would also be placed at EL-24.5 m, since there is no good foundation in the soft silty clay layer.

5) Road bridge

The road bridge would be provided at the downstream side of the pier. Dimensions of the road bridge are as follows:

	UTR	LTR
Type	Post-tensioning single-T girder bridge	Prestressed concrete girder bridge
Girder length	23.0 m	14.0 m
Number of spans	6 spans	2 spans
Bridge Length	138 m	28 m
Width	6 m	6 m
Live load	Linear load Evenly distrubuted load	5000 kg per meter 350 kg per sq.m
Bottom EL of girder	EL + 4.00 m	EL + 3.00 m

(4) Connection Channel

The tidal regulator connection channels would be excavated so as to short-cut the meandering portion of Mae Nam Bang Nara. The cross-section of the connection channel is given to drain with safety the design maximum flood of the tidal regulator at 50-year return period as examined by the hydraulic simulations study.

The UTR connection channel would excavate the meandering river course by making good use of the course of Khlong Sapi Yo which flows into Mae Nam Bang Nara. Its bottom elevation would be at the EL-4.0 m which is the same as the tidal regulator sill elevation, and the channel would have 150 m bed width and 1:3 side slope. The connection channel length would be 100 m at the upstream side and 600 m at the downstream side.

The bottom elevation of the LTR connection channel would be located at the EL-5.00 m which is the same as the regulator sill elevation, and the channel would be excavated with 30 m bed width and 1:3 side slope. The connection channel length would be 180 m at the upstream side and 160 m at the downstream side.

(5) Closure Dam

After completion of the regulators and connection channels, the old Mae Nam Bang Nara would be shut up with closure dams. These dams have 220 m length at UTR and 75 m length at LTR. The foundation ground at the closure dam consists of loose sand to soft clay stratum at the UTR site and soft clay stratum at the LTR site.

These dams would be constructed with a larger bottom width so as to distribute the load and prevent the sliding and settlement of the dam body. The dam body cross-section would be of a gentle slope embankment type with 1:5 side slope to realize the stabilization of embankment with regard to the river stream and the ebb and flood tides, because the dam body is saturated with water both during and after the construction work and most of the construction work is carried out underwater. Furthermore, the dam cross-section would take a symmetric configuration at the upstream and downstream sides because the differential water level of upstream and downstream is negligible. The dam would be embanked by using sandy soil materials to facilitate the elimination of pore water pressure, because the foundation is poor and the embankment work is carried out underwater.

The dam crest height is determined by adding a margin of safety of about 0.3 m to the 50-year return period flood water level, being EL+3.50 m at the UTR site and EL+2.50 m at the LTR site. Both dam heights are 8.50 m, respectively. The dam crest width would be 9.0 m which consists of 6.0 m road width and 1.5 m shoulder. The dam crest would be paved with laterite.

Stability calculation

The stability calculation referring to the sliding of the dam body consists of estimating the soil characteristics of each stratum of the foundation ground and confirming the safety by means of the slip circle method. The inner and outer water levels of the mean low water springs that bring about the maximum differential water level are regarded as design water level conditions, and the minimum design safety factor referring to sliding is regarded as 1.5. Results of stability calculations by computer indicate that safety factors of 1.6 at the UTR site and 1.7 at the LTR site can be secured.

Settlement calculation

Settlement of the dam body is caused either by the sinking of the foundation rubble mound or the lateral flow and consolidation of the foundation. Of the said causes, the consolidation settlement of the foundation clay stratum would be the main cause.

The extent of settlement is calculated by the Terzagi's formula with application of the compression index estimated from the liquied limit, because the experimental value of the consolidation coefficient has not been obtained yet:

$$S = \frac{Cc}{1 + Co} \log_{10} \frac{Po + \Delta P}{Po} H$$

where

- S : Settlement
- Cc : Compression index
- Co : Initial void ratio
- Po : Overburden pressure
- ΔP : Increase of pressure
- H : Thickness of layer

The total extent of settlement is estimated to be approximately 40 mm at the UTR site and approximately 70 mm at the LTR site.

(6) Structural Stability during the Extra-ordinary Floods

Two tidal regulators and those appurtenance facilities are designed in accordance with the 50-yr return period flood. The conditions of such structures during the extra-ordinary floods at 100-yr and 200-yr return periods are riviewed. The hydrauric conditions of those floods are as follows:

UTR	100-yr	200-yr
Upstream Water Level	EL+3.57 m	EL+3.84 m
Discharge	2,082 m^3/sec	2,279 m^3/sec
Velocity (at Regulator)	2.30 m/sec	2.43 m/sec
Velocity (at Channel)	1.63 m/sec	1.72 m/sec

LTR	100-yr	200-yr
Downstream Water Level		
(Gate closed)	EL+2.44 m	EL+2.64 m
Upstream Water Level		
(Gate opened)	EL+2.20 m	EL+2.34 m
Discharge	337 m^3/sec	389 m^3/sec
Velocity (at Regulator)	2.11 m/sec	2.37 m/sec
Velocity (at Channel)	1.03 m/sec	1.15 m/sec

Tip Elevation of the Gate

The tip elevation of the gates at full opening are EL+4.00 m at UTR and EL+3.00 m at LTR which are higher than 200-yr return period flood water level.

Crest Elevation of the Closure Dams

Crest eleavation of the closure dams are EL+3.50 m at UTR and EL+2.50 m at LTR, respectively, which are lower than the extraordinary flood level, therefore, the dams would be overtopped. Nevertheless, direct damages caused by overtopping would be minimized because the connetion roads which are elevated as lower as 0.5 m than the crest elevations of the dams, have been so designed as to be utilized as emergency spillways.

Connection Channels

Outskirts of the connection channels are deluged with the flood water during the extra-ordinary floods. Assuming that the flow area is that of the connection channels only, velocity of the 200 yr-return period flood is 1.72 m per sec at UTR and 1.15 m per sec at LTR. Generally, mean velocity of the river course is designed at 2 to 3 m per sec for safety of the both banks. Considering this point, those velocities would be no problem of the erosion for river bed or banks.

Access Roads

The water surface slope of the extra-ordinary floods would not be so steep considering the velocities as mentioned above. When the flood water over-flows the road, the differencial water level between up and downstream of access road would be small, so that the damages for the